THE EAST AFRICAN AGRICULTURAL JOURNAL

of

KENYA
TANGANYIKA
UGANDA AND
ZANZIBAR

COMMONWEALTH MYCOLOGICAL INSTITUTE
2 JUL 1952

Vol. XVII—No. 3

JANUARY
1952

Price
Sh. 2/50

IN THIS ISSUE:

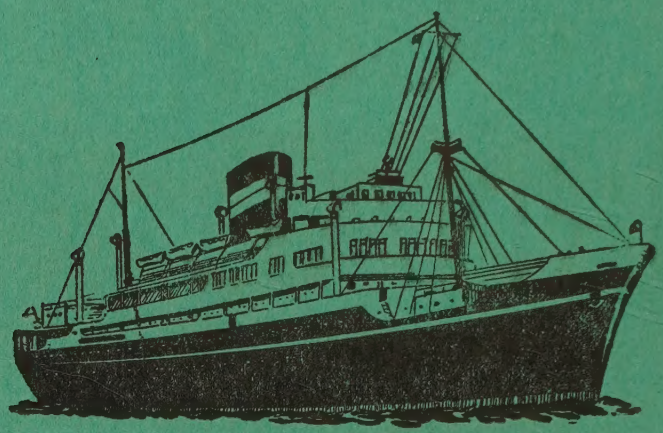
WOOD PRESERVATIVES FOR TERMITE CONTROL

FIBRE YIELD AND LEAF LENGTH OF SISAL

IS EAST AFRICA DRYING UP?

GRAZING AND GRASS BURNING EXPERIMENTS ON THE MSIMA RIVER STOCK FARM

COFFEE BERRY DISEASE (RAYNER)



KENYA and UGANDA to U.K.

In August the new 15,000 ton "KENYA" joined the "M" class vessels to augment the regular B.I. service between East Africa and United Kingdom. A sister ship the "UGANDA" will enter this service a year later.

BOMBAY/EAST AFRICAN SERVICE

Regular service from East African ports to Bombay at approximately fortnightly intervals. Sailings from Durban every month.

FOR FURTHER INFORMATION APPLY TO AGENTS

SMITH, MACKENZIE & CO., LTD.

MOMBASA • TANGA • DAR-ES-SALAAM • LINDI
NAIROBI • LAMU • ZANZIBAR • KAMPALA • MIKINDANI

For business or pleasure travel **B.I.**

EAST AFRICAN RAILWAYS & HARBOURS

WHAT'S IN A NAME?

EMULSION—?

SOLUTION—?

DUSTING POWDER—?

WETTABLE POWDER—?

THE EFFECT'S THE SAME.

IT'S JUST A MATTER OF USING

THE MOST SUITABLE AGENT

TO BRING—

Fairy D.D.T

—INTO CONTACT WITH THE INSECT PEST

TO BE DEALT WITH

We will gladly advise you on your insecticide problem if you will

WRITE TO R. E. Smith, McCrae, Johnson & Co., Ltd.
P.O. Box 310, Nairobi

or

CALL AT our office, Cambrian Building, Government Rd., Nairobi

(and at Box 1400, Kilindini Road, Mombasa)

NATIONAL BANK OF INDIA

LIMITED

(INCORPORATED IN THE UNITED KINGDOM)

ESTABLISHED IN 1863

Bankers to the Governments of Kenya, Uganda and Zanzibar

HEAD OFFICE: 26 BISHOPSGATE, LONDON, E.C.2.

Subscribed Capital	£4,562,500
Paid-up Capital	£2,281,250
Reserve Fund	£3,600,000

EVERY DESCRIPTION OF COMMERCIAL BANKING BUSINESS TRANSACTED

NIGHT SAFE BANKING FACILITIES AVAILABLE AT NAIROBI BRANCH

M&B

Horticultural Products for *Plant Welfare*

'DICOTOX' *brand* **Selective Weedkiller for turf**
trade mark

— for weed-free turf in gardens, greens and sports-grounds. Destroys a wide variety of weeds without injury to the grasses.

'SERADIX' *brand* **Root-forming Hormone preparation**
trade mark

— a reliable aid to the vigorous rooting of all types of cuttings.

BORDEAUX MIXTURE—M&B

— a traditionally useful fungicide specially packed to allow the preparation of fresh, effective suspension.

'DICOTOX' A *brand* **Selective Weedkiller for farm use**
trade mark

— effective against many species of weeds and harmless to wheat, barley and grassland. 'For cleaner fields and heavier yields.'

'PLANOFIX' *brand* **Fruit Drop Inhibitor**
trade mark

—an easily applied 'hormone' spray for preventing the fall of certain varieties of apples and pears before they can be picked. 'Planofix' can also be used to control and time the flowering and fruiting of pineapples.

GRAFTING WAX—M&B

—for the protection of exposed surfaces caused by grafting, pruning and lopping operations.

H194

MAY & BAKER LTD DAGENHAM, ENGLAND

Branch Office: P.O. Box 2056, Nairobi

Shell D-D Soil Fumigant—For the eradication of soil pests.

Fruit Sprays—
"Triona" for Citrus and Coffee trees.
"Dytrol" for Deciduous fruit trees.

Weedkillers—Total and selective weedkillers to meet all requirements.

Wood Preservatives—A full range of proved products to suit all methods of application.

General Agricultural Insecticides—Of particular interest to coffee growers: "Arkotine" D15; a 15 per cent D.D.T. emulsion.

"Malariol", "Malariol" H.S.—Normal and high-spreading larvicidal oils.

Fungicides—Shell copper fungicide, Shell dispersible sulphur, Shell power dusters.

"Shellestol" H—A liquid wetter and spreader.

SHELL

Shell Chemicals *DISTRIBUTING CO. OF AFRICA LTD.,*
P.O. BOX 5005, NAIROBI
Distributors of Shell Chemical Products

BARCLAYS BANK (DOMINION, COLONIAL AND OVERSEAS)

(Incorporated in the United Kingdom)

BRANCHES IN EAST AFRICA:

KENYA

Eldoret — Kisumu — Kitale — Mombasa — Nairobi (Agency at Thika)
Nakuru (Agencies at Gilgil and Molo) — Thomson's Falls

UGANDA

Fort Portal—Jinja—Kampala—Mbale—Tororo

ERITREA

Asmara — Massawa

TANGANYIKA TERRITORY

Arusha — Dodoma (Agency at Kongwa) — Dar es Salaam — Iringa — Lindi
Mbeya (Agency at Tukuyu) — Moshi — Mwanza — Tanga

AND THROUGHOUT

The Union of South Africa, Rhodesia, Nyasaland, Portuguese East Africa, South West Africa, British West Africa, British West Indies, British Guiana, British Honduras, Mauritius, Egypt, Sudan, Palestine, Gibraltar, Malta, Cyprus, Libya

WORLD-WIDE BANKING SERVICE FOR TRAVEL AND TRADE

London Offices: 29 Gracechurch Street, E.C. 3. Circus Place, London Wall, E.C. 2. Oceanic House, 1, Cockspur Street, S.W. 1.——Liverpool, Manchester, New York (Agency) and Hamburg

HEAD OFFICE: 54 LOMBARD STREET, LONDON, E.C.3

ARUSHA
BUKOBA
DAR ES SALAAM
ELDORET
JINJA
KAMPALA
KISUMU
KITALE
LINDI
MASAKA
MBALE
MOLO
MOMBASA

HEAD OFFICE:
10 Clements Lane,
Lombard Street,
LONDON, E.C. 4

MOSHI
MWANZA
NACHINGWEA
NAIROBI
NAKURU
NANYUKI
NYERI
SOROTI
TABORA
TANGA
THIKA
URAMBO
ZANZIBAR

LOCAL HEAD OFFICE:
Delamere Avenue,
NAIROBI

FOR ADVERTISING SPACE IN THIS JOURNAL

Apply to the

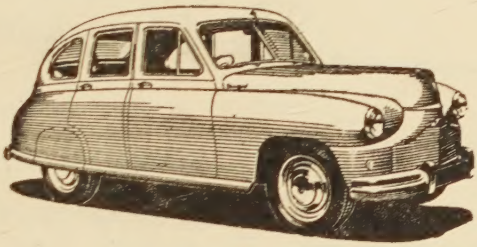
KENYA ADVERTISING CORPORATION, Ltd.

SHELL HOUSE, NAIROBI, KENYA

P.O. Box 563

LONDON AGENTS:
EXPORT ADVERTISING SERVICE, LTD.,
ROXBURGHE HOUSE 273/287 REGENT ST.
LONDON, W. 1.

MADE IN BRITAIN... DESIGNED FOR THE WORLD



STANDARD
VANGUARD

THE CAR TO SUIT KENYA CONDITIONS

18 HORSE-POWER—MEDIUM WEIGHT—STURDY CONSTRUCTION

8-in. ROAD CLEARANCE

Inquiries from:

Macgregor-Oates Motors, Ltd.

Box 406, 'Phone 2535, NAIROBI :: MOMBASA, Box 799, 'Phone 487

District Agents:

Nakuru: Boulton's Garage
Eldoret: Pretty Bros.
Kitale: Kerr & Howes Ltd.
Nyeri: Winter's Garage
Nanyuki: Kenya Mechanical Workshops Ltd.
Kisumu: Kisumu Motor Works Ltd.
Gilgil: Rift Valley Garage
Thomson's Falls: Engelbrecht's Garage

After a hard day's work...

there's nothing like a "TUSKER"

Especially when you know your efforts are responsible for the good barley which makes the good malt which makes "TUSKER" such a good beer

EAST AFRICAN BREWERIES LTD.

NAIROBI MOMBASA DAR ES SALAAM

Associated with H. & G. Simonds Ltd. Reading—England

BEALES & Co. Ltd.

VICTORIA STREET
NAIROBI

Tel. 2873
P.O. Box 320

★ The Dairy Farmers of East Africa. 1952 ★

Dear Sirs,

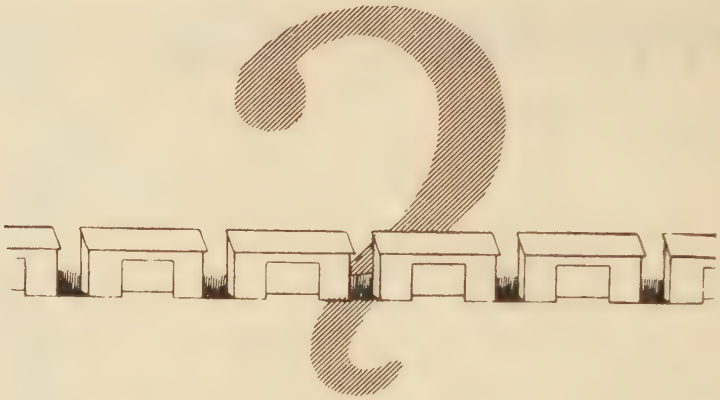
We specialize in Dairy Equipment.

Those of you who are already customers of ours are aware of the impressive range which constitutes our Dairy Equipment Stock. To those of you with whom we have not yet had the pleasure of serving we here enumerate a few of the items which can interest you.

Gascoigne Milking Machinery—All types. Non-pressure Multi-purpose Steam Sterilizers. 15 lb. and 30 lb. Pressure Dairy Sterilizers and Chests. Milk Churns, Churn Clips, 1-pt. Milk Bottles. Magazine Automatic Milk Bottle-cappers. Stainless Steel Seamless Milk Pails. Cow Yokes; 80 and 125 gal. Milk Coolers. Vacuum Clippers for Horses and Cattle. Milk Filters. Churn and Milk Bottle Brushes. Steaming Stands. Centrifugal and Piston Pumps. Small h.p. Villiers Petrol Engines. Stuart Turner Lighting Plants. Small Hand Posho Grinders. Tile Presses. Hammermills. Small Tractors.

That is but a few items—to give you an idea of how we can serve you and at all times we welcome your inquiries for any of your needs.

Yours faithfully,
BEALES & Co., Ltd.



The Answer to the Problem of

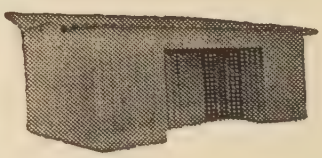
LABOUR HOUSING

Where temporary housing of a large labour force is concerned —A force which may have to be moved about at fairly frequent intervals—portability and ease of erection are essentials in the type of housing used. These points, plus adaptability to different requirements, are the main features of—

THE KINGSTON FRAMELESS ALUMINIUM HOUSE

Available for immediate delivery

Write or ask for descriptive pamphlet from and branch of G. & R.



Gailey & Roberts Ltd.

KENYA UGANDA TANGANYIKA

BOVILL, MATHESON
AND CO., LIMITED

Head Office:
QUEENSWAY HOUSE
YORK STREET, NAIROBI
(P.O. Box 1051 / Phone 2547) NAIROBI, KENYA

Branches:

Kenya—
Kericho P.O. Box 56

Uganda—
Kampala P.O. Box 609

Tanganyika Territory—
Arusha P.O. Box 345
Tanga P.O. Box 112

MANAGING AGENTS
AND MERCHANTS

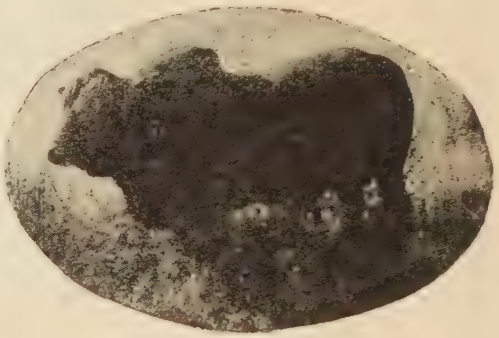
The Proprietors of Agricultural, Industrial and Mining Undertakings are offered by the Company—Managing and Visiting Agency, Accountancy, Secretarial, Investment and Marketing Services

London Correspondents:
TREATT, BOVILL & Co., Limited
Plantation House, Fenchurch St., London E.C.3 Tel. Mansion House 7471/3

Associated Company
J. W. MILLIGAN & Co., Ltd.
Land and Estate Agents
Nairobi, Arusha, Kericho, Kampala, Tanga

LAIKIPIA ZEBU CATTLE

BRED IN THE LAIKIPIA DISTRICT, KENYA, FROM A HERD OF BORAN CATTLE ESTABLISHED IN 1919



PEDIGREED AND HERD BULLS FOR SALE FROM OUR POLLED AND HORNED ZEBU HERDS OF BEEF AND DAIRY CATTLE

For particulars apply:—

NDURUMO LIMITED, RUMURUTI, KENYA COLONY

HIDES

BUYERS of HIDES and GOATSKINS

CONSIGNMENTS FROM FARMS AND BUTCHERIES RAILED TO OUR NEAREST BUYING DEPOT WILL BE WEIGHED AND VALUED UNDER EXPERT SUPERVISION

THE AFRICAN MERCANTILE CO., LTD.

(INCORPORATED IN ENGLAND)

Branches at : KAMPALA, MBALE, KISUMU, NAIROBI, MOMBASA, TANGA, DAR ES SALAAM, BUKOBA, ZANZIBAR, LINDI, MTWARA

ALWAYS IN THE MARKET FOR LARGE OR SMALL QUANTITIES AT COMPETITIVE PRICES

Telegraphic Address: NAVIGATION

GOAT & SHEEP SKINS

"SOREXA"

THE NEW ANTI-COAGULANT RODENTICIDE

"SOREXA" is a new type of rodenticide, the active ingredient being an anti-coagulant chemical. Small multiple doses will exterminate rats and mice by causing spontaneous internal hæmorrhage.

"SOREXA" is relatively harmless to man or domestic animals, and may be safely used where poison or "virus" rodenticides would be dangerous. It is undetectable by rodents.

Agents and Distributors in East Africa:—

ARTHUR A. WHITE, LTD.

P.O. Box 618, NAIROBI & WESTLANDS ARCADE

CHEMISTS AND VETERINARY SPECIALISTS

TELE. 2913

Bigger Litters-Better Growth

The experienced pig breeder uses 1 pint of SOLVITAX per cwt. of dry food (i.e. 2 tablespoons to 6 lbs).

That means bigger and healthier litters—trouble-free farrowing—a longer breeding life for the sow. It also means a bigger live-weight gain from the same quantity of food.

SOLVITAX puts 'profit' into pigs. But—to get reliable results—your feed must contain 1 pint of Cod Liver Oil per cwt. of dry food.

Write for free copies of the pig and poultry booklets.

SOLVITAX
Pure COD LIVER OIL

Sold by Corn Merchants and Chemists in all sizes

BRITISH COD LIVER OILS (Hull & Grimsby) Ltd
St. Andrew's Dock, Hull

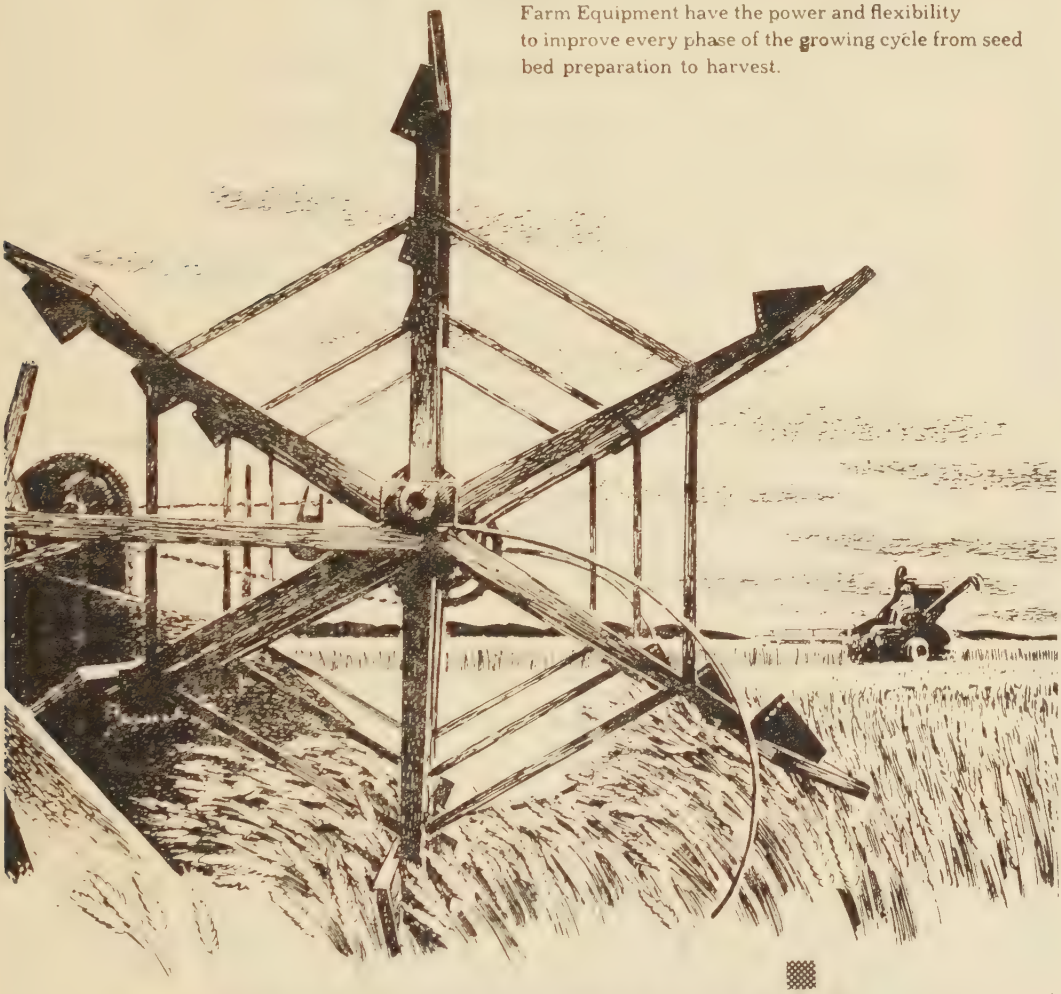
HOWSE & McGEORGE LIMITED

National strength is a food project

"The base of the social pyramid rests today where it has always rested – upon the land."

Agriculture will always stand foremost as a vital industry, a source of *physical and economic security*. Nevertheless, it hasn't yet become the source of strength it should! There is need for agricultural advancement everywhere and the answer to this problem is *mechanized agriculture*

Whether crops are grown for food or fibre . . whether farms are measured in tens or thousands of acres . . . McCormick International Farm Tractors and Farm Equipment have the power and flexibility to improve every phase of the growing cycle from seed bed preparation to harvest.



INTERNATIONAL HARVESTER

BUILDER OF ESSENTIAL EQUIPMENT FOR ESSENTIAL WORK

McCormick International Farm Equipment • International Trucks • International Industrial Power • International Harvester Refrigeration

INTERNATIONAL HARVESTER COMPANY OF EAST AFRICA LIMITED

Jeevanjee Street, Nairobi, P.O. Box 668

THE SOUTH BRITISH INSURANCE CO., LTD.

(INCORPORATED IN NEW ZEALAND)
ESTABLISHED 1872

Principal Office for East Africa

South British Building
Mombasa

P.O. Box 103 Telephone 529

Telegraphic Address: UBIQUITOUS, MOMBASA

BRANCHES AND AGENCIES TRANSACTING INSURANCE BUSINESS THROUGHOUT EAST AFRICA, THE BELGIAN CONGO, ETHIOPIA, ERITREA AND ADEN

Manager for East Africa
E. S. BROOKS

A. BAUMANN & Co. Ltd.

PRODUCE EXPORTERS

COFFEE, BEANS, CEREALS, SUNFLOWER SEED, CHILLIES, WATTLE BARK, Etc.

Offers and Samples to P.O. Box 323, Mombasa

IMPORTERS

BUILDING MATERIALS.
HARDWARE AND GENERAL.
JUTE AND TEXTILES.
ELECTRICAL EQUIPMENT.
DIESEL ENGINES.
ENGINEERING SUPPLIES.

Inquiries to:

P.O. Box 323, Mombasa
P.O. Box 538, Nairobi
P.O. Box 277, Dar es Salaam
P.O. Box 335, Kampala
P.O. Box 146, Lindi

The 'Agrocides' protect most of your crops against their worst enemies

The 'Agrocide' products are insecticidal dusts and sprays containing the powerful insecticide 'Gammexane' gamma BHC which is deadly to a wide range of insect pests in both horticulture and agriculture, but harmless to man and warm blooded animals. Growers can thus buy 'Agrocide' products with complete confidence in their effectiveness and safety.

Manufactured by:
PLANT PROTECTION LTD., 61 CURZON STREET, LONDON, W.1
Agents in East Africa:
AFRICAN EXPLOSIVES & CHEMICAL INDUSTRIES (E.A.) LTD.,
MANSION HOUSE, P.O. BOX 5480, NAIROBI

But I've switched off . . .

Maybe you have, but that's when

CORROSION

really gets to work

Research has proved that *corrosion* is the major cause of engine wear, and even tough-built-for-tough-work farm tractors do not escape.

Shell X-100 Motor Oil contains additives which neutralise corrosive acids, making the oil spread evenly and firmly, leaving a strong film on *all* engine parts—*when you switch off*. Still there when you re-start, that film has shielded the engine from corrosion while the tractor was "off duty" or standing.

You must PROTECT the engine

Lubricate with

SHELL X-100 MOTOR OIL

DETERGENT...STABLE...PROTECTIVE

Liver Fluke losses can be prevented

A high percentage of cattle livers are condemned every year because of this disease representing a heavy financial loss to the farmer and stockbreeder. Liver Fluke Disease must not be ignored as it not only reduces milk yield and lowers the quality and quantity of the meat produced, but also affects fertility and—in the case of sheep—severely affects wool production. Avlothane Brand Hexochloroethane is the safe cure for Liver Fluke and has a powerful action against mature and immature Liver Flukes so that the persistence of the disease is lowered and eventually eradicated.

Avlothane is available as a dispensible powder in 500 gms. price Shgs. 5/50 and 3 Kilo tins price Shgs. 25/70.

ICI

Product of Imperial Chemical (Pharmaceuticals) Ltd., a subsidiary of Imperial Chemical Industries

AFRICAN EXPLOSIVES AND CHEMICAL INDUSTRIES (EAST AFRICA) LIMITED

AE&CI

Mansion House, P.O. Box 5480. NAIROBI. Telephone 2506.

Main Distributors: All branches of Smith Mackenzie & Co. Ltd.

Manufacturers of Machinery

for Preparing

COFFEE, RICE, MAIZE, WHEAT & ROOT CROPS

Send for Particulars of:

MAXIM ROOT CUTTERS

WIZARD AUTOMATIC HAMMER MILLS

HAND OPERATED MAIZE MILLS

BRITISH EAST AFRICA CORPORATION LTD.

Branches Throughout East Africa

Contract Spraying

In Cereal crops and pastureland against weeds and pests of all kinds also Coffee against Hemileia and Thrips

Spraying Equipment and Chemicals

Phenoxylene and **Phordene**

Two highly selective hormone weed killers in cereal crops and pastureland

used with the "WEEDMASTER"

A low volume sprayer Tractor mounted and easily fitted to any make. Capacity 45 gallons spray 50 acres per day

Blitox and **Psylortox**

Blitox contains 50 per cent Copper Fungicide for Tonic, and anti-Hemileia spraying. Psylortox a D.D.T. emulsion for insecticide spraying

used with the "COFFEEKING"

Tractor mounted. Fifty-gallon capacity non-corroding tank. Adjustable pressures to 80 lb. per square inch

PEST CONTROL

(E.A.), LTD.

P.O. Box 45, Ruiru - Phone 29 - Grams: "Pestcont."

THE

EAST AFRICAN AGRICULTURAL JOURNAL

VOL. XVII—No. 3 **JANUARY, 1952**

Printed and published by the Government Printer, Nairobi.

Issued under the Authority of the East Africa High Commission and published every three months—July, October, January, April. Volume consists of four issues (commencing July issue).

Editorial Board: Director of E.A. Agriculture and Forestry Research Organization. Director of E.A. Veterinary Research Organization. Directors of Agriculture, Kenya, Tanganyika, Uganda and Zanzibar. Directors of Veterinary Services, Kenya, Tanganyika and Uganda. Conservators of Forests, Kenya, Tanganyika and Uganda.

Executive Committee.—Director of E.A. Agriculture and Forestry Research Organization. Director of E.A. Veterinary Research Organization. The Editor.

EDITOR: D. W. DUTHIE,

E.A.A.F.R.O., P.O. BOX 21, KIKUYU, KENYA

Subscription Sh. 10 per volume including postage, payable to the Editor. Subscribers are advised to remit postal orders in payment, otherwise bank commission must be added in the case of cheques.

The Editor does not hold himself responsible for opinions expressed by contributors.

Matter submitted for publication should preferably be sent through the local member of the Editorial Board. Double spacing should be used in typescript. Contributors receive 25 prints of their articles free. Additional copies may be obtained on payment if asked for in advance. Prints bear the same page numbers as the original articles in the Journal, except where, to meet a contributor's wishes, prints are supplied before publication has been completed.

Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to the Editor.

CONTENTS

	PAGE
Looking Back	107
A Note on Wood Preservatives for Termite Control	109
Pea Blight	110
Fibre Yield and Leaf Length of Agave Sisalana	111
Is East Africa Drying Up?	116
Grass Burning Experiments on the Msima River Stock Farm, Southern Highlands, Tanganyika	119
Coffee Berry Disease—A Survey of Investigations carried out up to 1950	130

INDEX TO ADVERTISERS

	PAGE
A. Baumann & Co., Ltd.	XVI
African Explosives & Chemical Industries (E.A.), Ltd.	XVII & XIX
African Mercantile Co., Ltd.	XIII
Arthur A. White, Ltd.	XIII
Barclays Bank (D.C. & O.)	V
Beales & Co., Ltd.	IX
Bovill, Matheson & Co., Ltd.	XI
British East Africa Corporation, Ltd.	XX
Caltex (Africa), Ltd.	COVER PAGE 3
Craelius East African Drilling Co., Ltd.	V
Dunlop Tyres	COVER PAGE 4
East African Breweries, Ltd.	VIII
East African Railways and Harbours	I
Gailey & Roberts, Ltd.	X
Howse & McGeorge, Ltd.	XIV
International Harvester Co. of E.A., Ltd.	XV
Kenya Advertising Corporation, Ltd.	VI
Macgregor-Oates Motors, Ltd.	VII
May & Baker Co. (E.A.), Ltd.	III
National Bank of India, Ltd.	III
Ndurumo, Ltd.	XII
Pest Control (E.A.) Ltd.	XXI
R. E. Smith, McCrae, Johnson & Co., Ltd.	II
Shell Chemicals, Ltd.	IV
Shell Co. of E.A., Ltd.	XVIII
Smith, Mackenzie & Co., Ltd.	COVER PAGE 2
South British Insurance Co., Ltd.	XVI
Standard Bank of South Africa, Ltd.	VI

LOOKING BACK

Publication of this issue has been delayed while negotiations for a financial subsidy were being carried on with the three East African Governments; this has now been arranged. The opportunity has been taken to look back over the development of the Journal since its inception.

At the South and East African Agricultural Conference held in Nairobi in 1926, the Director of Agriculture, Kenya, read a paper advocating the establishment of an agricultural journal for East Africa, and suggested that it should be edited from the inter-territorial agricultural research station which was then being planned to replace the Biologisch-Landwirtschaftlichen Institut which had been set up at Amani by the German Government in 1902. A monthly scientific journal *Der Pflanzer* had been published from Amani between 1905 and 1914.

During the subsequent seven years, up to 1933, a considerable amount of discussion and correspondence centred round the proposed agricultural journal and an offer was made by the Director of Agriculture, Kenya, that it should be edited and published by his Department under the title of *The East African Agricultural Journal*. By the middle of 1933 arrangements had almost been completed for publication of the first number in this way, but the retirement of Mr. Holm from the Directorship of the Kenya Department of Agriculture appears to have delayed implementation of the scheme.

The subject was reopened in 1934, and the conclusion was reached that the new Journal should be edited at the East African Agricultural Research Station, Amani, but the publication and management should be carried out in Nairobi. Since it seemed extremely unlikely that the Journal could be self-supporting financially, the East African Governments agreed to share the deficits, and final arrangements were made early in 1935 for the new Journal to be started.

The first number appeared in July, 1935, and the Journal was published every second month until the end of Volume 5, 1940; thereafter it appeared quarterly. The Director of the Amani Research Station was appointed Editor and one of his staff was appointed Assistant Editor. The Government Printer, Kenya, and the Director of Agriculture, Kenya, shared the responsibility for publication and business management and the accounts were kept in the offices of the East African Governors' Conference. Overhead expenses were kept to a minimum by the fact that the only charge for editing or management was a small honorarium to the Assistant Editor.

When, in 1948, the staff of the Amani Research Station was absorbed into the East African Agriculture and Forestry Research Organization, the post of Assistant Editor was abolished, and one of the staff of E.A.A.F.R.O. was appointed Editor, under joint control of the Directors of E.A.A.F.R.O. and the East African Veterinary Research Organization. This change removed the only overhead expense, namely the honorarium to the Assistant Editor, but, unfortunately, the Kenya Government Printer found that he could no longer carry the business management without charge. Pending new financial arrangements, E.A.A.F.R.O. took over the business management in mid-1950 as a matter of urgency. Revised arrangements have now been made whereby the East African Governments share between them the salary of the business manager and the annual working loss. The Editor will normally be a member of the staff of E.A.A.F.R.O. or E.A.V.R.O.: his services are given without charge.

It is not easy to calculate figures for the annual working account, since subscriptions are frequently received for several years in advance. Thus, income and expenditure in any one year do not reflect the true working balance, but, looking back on financial reports, it seems that this Journal has been run at an average loss of approximately £70 a year. Grants have been received from the East African Governments on three occasions, and the annual subscription was raised from Sh. 5 to Sh. 10 in 1951, but rising costs of publication, particularly in the last year or two, have offset the financial effect of a steady increase in the number of copies sold, from 700 in 1937 to 1,500 in 1950. Unfortunately a considerable number of subscriptions have been cancelled since the price was raised.

A surprisingly large proportion of the subscriptions (36 per cent at present) comes from outside British East Africa, and the wide distribution of the Journal is shown by the fact that there are subscribers in 61 countries and dependencies, with 15 more on the exchange list. Non-British territories are strongly represented, since there are subscribers in seven European countries, nine non-British American countries, and 13 non-British tropical countries. Eleven other foreign countries receive the Journal on exchange.

A review of the subjects treated in the existing volumes of the Journal brings out points of some interest. From the first number in July, 1935, to the October, 1951, issue, some 930 original articles and notes have appeared, covering a wide range of subjects in agriculture, veterinary science, forestry, biology and farm practice. Those subjects which can be grouped under animal industry account for 129 articles, while there have been 59 articles on animal diseases. Of the total of 233 articles on crops, coffee has by far the largest number, since 67 of these have appeared, dealing with a wide range of aspects of coffee farming, including pests and diseases. There have been 25 articles on sisal and 15 on cotton, but pyrethrum and tea account for only 15. Now that the East African Tea Research Institute has been set up, it is anticipated that a rapidly expanding tea industry in East Africa will be assisted by further articles of practical and scientific value.

Farm practice is represented by 51 articles, but there must be a large volume of practical knowledge hidden in the minds of those who have had many years' experience of farming in East Africa, and it is a matter of importance that this knowledge should be available to others. It is hoped, therefore, that more contributions will be received from farmers who have solved practical farming problems.

Articles dealing with native agricultural practices, 66 in all, describe the work of agricultural officers in native areas, and some of these provide valuable records of tribal systems which may die out in time. These are allied to the 56 articles which have appeared on land use and the conservation of soil and water. The work which is now being carried out on improving soil fertility by the proper care and management of grasslands has a background in 36 articles on the subject of grasses and legumes, while investigations on soils and fertilizers have provided 41 articles. Forestry subjects are dealt with in 37 articles, many of which cater for the farmer as well as the forester. The growing importance of plantation timber in the economy of East Africa is likely to cause an increase in the proportion of forestry articles, many of which have a world-wide appeal.

Quality, not quantity, is the real test, but perusal of the back numbers leaves the impression that the original sponsors of the Journal set a high standard which has been maintained throughout the years. On that line of thought it must be remembered that an individual number of a technical journal is not, in itself, an entity like one issue of a daily newspaper. It is only the accumulation of knowledge in a number of volumes which shows the real value of a Journal such as this, and the sixteen complete volumes form an encyclopædia of East African agriculture, veterinary science and forestry which will provide answers to a very large number of problems. The range of subjects seems unusually wide, but, with the exception of two or three articles on fisheries, they could be grouped into one broad aim—the raising of the productivity of the land.

D.W.D.

A NEW AFRICAN LIBRARY SERVICE IN KENYA

It is announced that arrangements have now been made to start a Postal Library Service for all Africans in Kenya. This service is being run by the Libraries Section of the East African Literature Bureau. A catalogue of the books available for borrowing will be issued to each registered reader, and books will be sent on request to the reader by post, and may be returned to the library in the same way. Full particulars of how to become a member will be sent to interested readers on application to: The Librarian, E.A. Literature Bureau, P.O. Box 2022, Nairobi.

A NOTE ON WOOD PRESERVATIVES FOR TERMITE CONTROL

By W. Victor Harris, Termite Research Unit, East African Agriculture and Forestry Research Organization

(*Received for publication on 17th October,* 1951)

D.D.T. and Benzene Hexachloride have been shown to have some value in protecting timber from damage by soil-dwelling termites. (This Journal, Vol. 14, page 49; Vol. 14, page 187.) Timber which had been dipped for 30 minutes in a 5 per cent solution in oil, or in an emulsion of similar strength of either chemical was undamaged after two years in termite-infested soil.

Four proprietary wood preservatives were obtained for testing against termites in 1949. Three of these were compared with a D.D.T. miscible oil emulsion (17 per cent D.D.T., kindly provided by Messrs. Shell Chemicals, Ltd., Nairobi), using slabs of timber dipped for 30 minutes in cold fluid as in the previous trials. In a second test all four preservatives were used for treating small Eucalyptus logs by the "hot and cold" process. The trial was carried out at the Kawanda Research Station of the Uganda Department of Agriculture on two "graveyard" sites already proved to be well infested with wood-destroying termites of the genera Macrotermes, Microtermes and Pseudacanthotermes. The assistance given by Mr. A. P. G. Michelmore, Senior Entomologist, and his staff is gratefully acknowledged.

Cold Dipping

For the first test, 75 slabs of a local softwood "nongo", *Albizzia* sp., were cut from 1-in. planks, 6 in. wide and 9 in. long. Of these, 15 remained untreated as controls and the remaining 60 were soaked for 30 minutes in batches of 15 in four solutions, viz. D.D.T. emulsion and three preservatives. After draining, the slabs were divided into three groups of five slabs from each treatment and five untreated, and each group was arranged as a Latin square, chosen at random from tables, in "graveyards". Two groups were on opposite sides of an active mound of *Macrotermes natalensis,* the third was some distance away.

After three months exposure, all the 15 untreated slabs showed some sign of termite damage, and seven had been eaten away below ground almost completely.

After 25 months, all the slabs were removed and the damage done by termites, to parts which had been buried, recorded.

Amount of damage	DDT	Treatment			Untreated
		No. 1	No. 2	No. 3	
No damage whatever	14	3	0	0	0
Exploratory nibbles	1	2	2	0	1
Slight (up to ¼ eaten)	0	3	2	0	2
Heavy (up to ¾ eaten)	0	4	3	5	0
Completely destroyed	0	3	8	10	12

No preservative achieved a degree of protection under these conditions equal to that given by D.D.T. There are indications that the three preservatives were not equal in their ability to make wood unpalatable to termites.

Hot and Cold Treatment

The second test consisted of 12 blocks cut from recently felled *Eucalyptus saligna,* with the bark removed, roughly 6 in. in diameter and 12 in. long (about 1/5 cu. ft.). Four blocks were left untreated as controls. The remainder were treated in pairs in the four preservatives by the "hot and cold" method, which requires the timber to be submersed in hot fluid, which is kept hot to counteract the cooling effect of the timber, and then allowed to cool down slowly overnight. The heat drives air out of the surface cells of the timber, and on cooling this is replaced by preservative, thus producing a greater absorption of preservative than is possible with brushing or cold dipping for an equal period. Preserving fluid was absorbed on average at the rate of from 6 to 7 lb. per cubic foot of timber. Then the blocks were randomized in two rows on opposite sides of the Macrotermes mound, between two "graveyards". As with the slabs, rather more than half of each block was buried below soil level, and the earth rammed down firmly around them.

After three months' exposure three out of the four untreated blocks were removed because they had already lost more than three-quarters of the buried portions. The fourth untreated block could not be found at the end

of the trial when, after 25 months all the blocks were removed for examination.

Amount of damage	Treatment				Untreated
	No. 1	No. 2	No. 3	No. 4	
No damage whatever	2	—	—	—	—
Exploratory nibbles	—	2	—	2	—
Very slight	—	—	2	—	—
Completely destroyed	—	—	—	—	4

Three preservatives gave complete protection under these conditions. The fourth allowed a small amount of damage to be done at soil level, due no doubt to the leaching effect of sun and rain on the protective layer exposed above the ground.

Conclusions

When applied to soft-wood slabs by dipping for 30 minutes, three proprietary wood preservatives failed to give complete protection against soil-dwelling termites. They varied in the degree of protection which they afforded. A D.D.T. miscible oil concentrate used for comparison gave complete protection for two years, though it did not prevent some rotting.

These three preservatives, and an additional one, all gave good results when the "hot and cold" method of treating timber was employed. Slight differences in efficiency observed, which would probably increase with time, corresponded to the indications obtained in the dipping test.

Dipping and brushing are not efficient methods for applying wood preservatives to protect timber against soil-dwelling termites. Proprietary preservatives which failed when applied by cold dipping, gave good results when the "hot and cold" method was employed. The trial lasted two years. In order to ensure the protection of timber for long periods, impregnation is desirable in tanks where controlled conditions of temperature and pressure are obtainable.

PEA BLIGHT

By G. B. Wallace and Maud M. Wallace, Department of Agriculture, Tanganyika Territory

(*Received for publication on 15th December,* 1951)

A bacterial blight disease of garden peas and sweet peas was described in the July, 1951, number of this Journal. The bacterium concerned has been investigated by Dr. W. J. Dowson and Mr. R. A. Lelliott of the Botany School, Cambridge, and their assistance is gratefully acknowledged.

These investigators have informed us that after comparison with American and Australian strains and the original description they have decided that the Tanganyika bacterium from blighted peas is a strain of *Pseudomonas pisi,* Sackett.

There have been no further cases in the Moshi area. On the other hand outbreaks were found in the Usambara Mountains: in gardens at Amani in mid-November and in two gardens above Lushoto at the end of November. If these outbreaks have originated in the Moshi district, it can only be concluded that the intensive efforts made to restrict and eliminate the disease have failed. But it is learned that there have been introductions of pea seed to the Usambara Mountains from outside Tanganyika, and the new cases have more than likely arisen independently of the original ones.

Drastic measures for control in Tanganyika can no longer be justified, but the attention of growers is called to the control measures advised in the previous article. Pea Blight has been declared a disease for the purposes of the Plant Protection Ordinance in Tanganyika.

FIBRE YIELD AND LEAF LENGTH OF AGAVE SISALANA

By J. G. Thieme, Research Director, Sisal Products (E.A.) Ltd., P.O. Ruiru, Kenya Colony

(*Received for publication on* 10*th October,* 1951)

It is often more or less taken for granted that a higher production of sisal leaves per acre means a higher yield of fibre. This would indeed be the case if the leaves contain in both cases the same amount of fibre, in other words if they have about the same length.

The last condition, however, will not always be fulfilled: a higher production of leaves may have been obtained at the cost of the length of the leaf; more leaves may have been produced per acre, but the average length of the leaves may be shorter. In such a case how will the fibre yield be affected? Is there a distinct relation between fibre yield and length of leaf?

In investigating this matter in Sumatra some years ago, the author came to the conclusion that the usual way of expressing the fibre content of a leaf as a percentage of its weight is not a very practical one in this connexion. True, other agricultural industries calculate in the same way. The sugar manufacturer will find that his cane contains 10 or 12 per cent of sugar; the starch manufacturer will be proud if the analysis of his raw material shows 30 per cent instead of 28 per cent of starch; the producer of palm oil will know that he gets a higher yield if he gets an average of, say, 18 per cent of oil of the fruits instead of 16 per cent previously.

In all these and various other cases this way of calculating the product as a percentage of the raw material is a logical one. The product in question, be it sugar or starch or oil, is a reserve food of the plant, synthetized in the plant during a rather short time interval, the period of ripening, and decomposed again afterwards. This period of ripening can be as short as a few weeks or even days; it can therefore be assumed that the total weight of raw material (sugar cane, oil fruits, starch roots, etc.) will not vary considerably during this short period, compared with the very big variations in chemical composition.

These considerations, however, do not apply to fibres. Fibres, whether sisal or others, are not food reserves; they are not produced by the plant during a short period of ripeness at race-speed. They form part of the structure of the leaf, the skeleton as it were, and this skeleton will grow with the growing leaf, but in a steady, regular way without seasonal "peaks".

If therefore the percentage of fibre of a leaf has changed within a relatively short interval, it is very unlikely that something has happened to the fibre. It is far more probable that the change has been caused not by the fibre but by the rest of the leaf. There may have been a period of drought with drying out of the leaf, or possibly there has been a period of rain and the leaf is more juicy; the result will be that a higher or a lower fibre content will be found. In both cases the production of fibre per acre will be the same.

Sturdy and hardy, as agave leaves are, they are still susceptible to changes caused by varying humidity. For example, in Java, where the dry season is much more pronounced than in Sumatra, planters are used to the fact that the leaves have an output of about 5 per cent fibres in the dry season and about 3½ per cent in the wet monsoon, without any substantial change in the yield of fibre per acre.

In studying the relationship between leaf length and fibre yield, the author expressed the fibre, not as a percentage of the weight of the leaf, but as an independent figure of grams of fibre per leaf. These "grams of fibre per leaf" were compared with the length of the leaf, regardless of the weight of the leaf.

The experiments were made in this way: bundles of leaves from a certain cut and of exactly the same length were decorticated and the flume waste retted; the line fibre obtained and the clean, handwashed flume tow were weighed, the weights were corrected at a standard water content of 10 per cent and added, and divided by the number of leaves. When grams of fibre per leaf against the length of the leaf were plotted separately for the leaves of the same cut (assumed to be of the same average age), a very distinct correlation between length and fibre was found. The regression fibre on length, showing the increase of fibre weight per length unit, was not a linear one; the regression function had the form of a parabola. Taking the logarithms of fibre and length and determining their regression function, the parameter and the power of the original parabola could be found.

In this way the author found the following formula for the relationship between fibre and length:—

(1) Grams of Fibre per leaf = $K_1 \times$ (Length of Leaf in cm.) K_2.

In this formula (which is published here for the first time), the power K_2 is practically independent of the age of the plant (cut), and varies between 2 and 3, with an average of 2.45 for Sumatra leaves of *Agave sisalana*. The parameter K_1 varies for the cuts, being obviously dependent on the age of the plant, or rather on the number of the leaf in the life-cycle of the plant. K_1 is higher for younger and lower for older plants and is a figure of about 0.0003 to 0.0005 (or 3×10^{-4} to 5×10^{-4}).

In Sumatra the author worked out elaborate tables from many hundreds of tests, in which the amount of fibre in grams per leaf could be found for leaves of various lengths and cuts. These tables were lost during the war and the figures given here are from memory and only approximate. However, even without correct figures for K_1 for various cuts, formula (1) will be very useful to the planter. It shows in any case how much more or less fibre will be produced if the average length of the leaves be higher or lower.

For example, a leaf of double length does not contain twice as much fibre but $2^{2.45}$ or about $5\frac{1}{2}$ times as much. As shorter leaves frequently give higher losses in decortication, the difference in the fibre actually produced will be still bigger. It can therefore be assumed that leaves of the double length (but same age) will give a fibre production about six times higher. This enormous influence of leaf length on fibre content is often not sufficiently realized.

If the amount of fibre in a leaf of 3 ft. length is called 100, shorter or longer leaves of the same age will contain:—

Length of Leaf	Fibre per Leaf Per cent Fibre per Leaf of 3 ft.
Feet.	*Per cent.*
$1\frac{1}{2}$	18·3
2	37·0
$2\frac{1}{2}$	64·0
3	100·0
$3\frac{1}{2}$	145·9
4	202·5
$4\frac{1}{2}$	270·0
5	349·6
$5\frac{1}{2}$	441·6
6	546·4

The explanation for this powerful influence of length on fibre content is that length influences the fibres in three ways: when the leaf is growing in length the fibres become longer, they become thicker and they multiply by the formation of new fibres.

It may be mentioned in this connexion that there is not much of a correlation between length and thickness (fineness) of the fibres of any particular leaf. It is true that the longest fibres of a leaf, the "backbone" in the middle of the leaf by which the needle is formed, are also the thickest fibres; but there are also short thick and long thin fibres, enough to spoil the correlation between length and thickness that one might expect. However, when normal commercial line fibre, originating from leaves of various lengths, is tested, a significant correlation between length and fineness of the fibres will be found. This correlation is due to the fact that as an average the longer (and older) leaves contain thicker fibres. Two random samples of Kenya sisal (commercial line fibre) may illustrate this:—

	Fibres from same strand	Fibres from strands of various length
Length (inches):		
Minimum	23 in.	17 in.
Maximum	47 in.	46 in.
Arithm. mean ..	39·8 in.	34·0 in.
Stand. Deviation ..	5·4	7·2
Coeff. of Variation ..	13·6%	21·1%
Fineness (mgr. per 10 in):		
Minimum	2	3
Maximum	27	26
Arith. mean	13·4	9·1
Correlation Coefficient:		
Fineness/Length ..	0·25	0·79
Regression:		
Fineness on Length ..	0·07	0·20

It is obvious that there will also be a correlation between length and weight of leaves. It was found by the author in Sumatra (and verified here in Kenya) that the weight of a leaf grows with the second power of the length. Therefore:—

(2) Weight of leaf in grams = $K_3 \times$ (Length of Leaf in cm.)^2.

The parameter K_3 in this formula is about 0.06, dependent on the age of the plant but also on other influences like drought, etc.

The interesting feature is that the length of the leaf has a bigger influence on the amount of fibre than on the weight of the leaf. There-

fore a longer leaf contains more fibre in relation to its weight than a shorter one, so if the fibre output is expressed as a percentage of the weight of the leaf (as usual), this will also be dependent on the leaf length, though to a much lesser degree.

From formula (1) and (2) the relationship between fibre output and leaf length can be calculated; it is (approximately):—

(3) Fibre per cent weight of leaf = $0.5 \times \sqrt{\text{Length in cm.}}$ (or about half the root of the length).

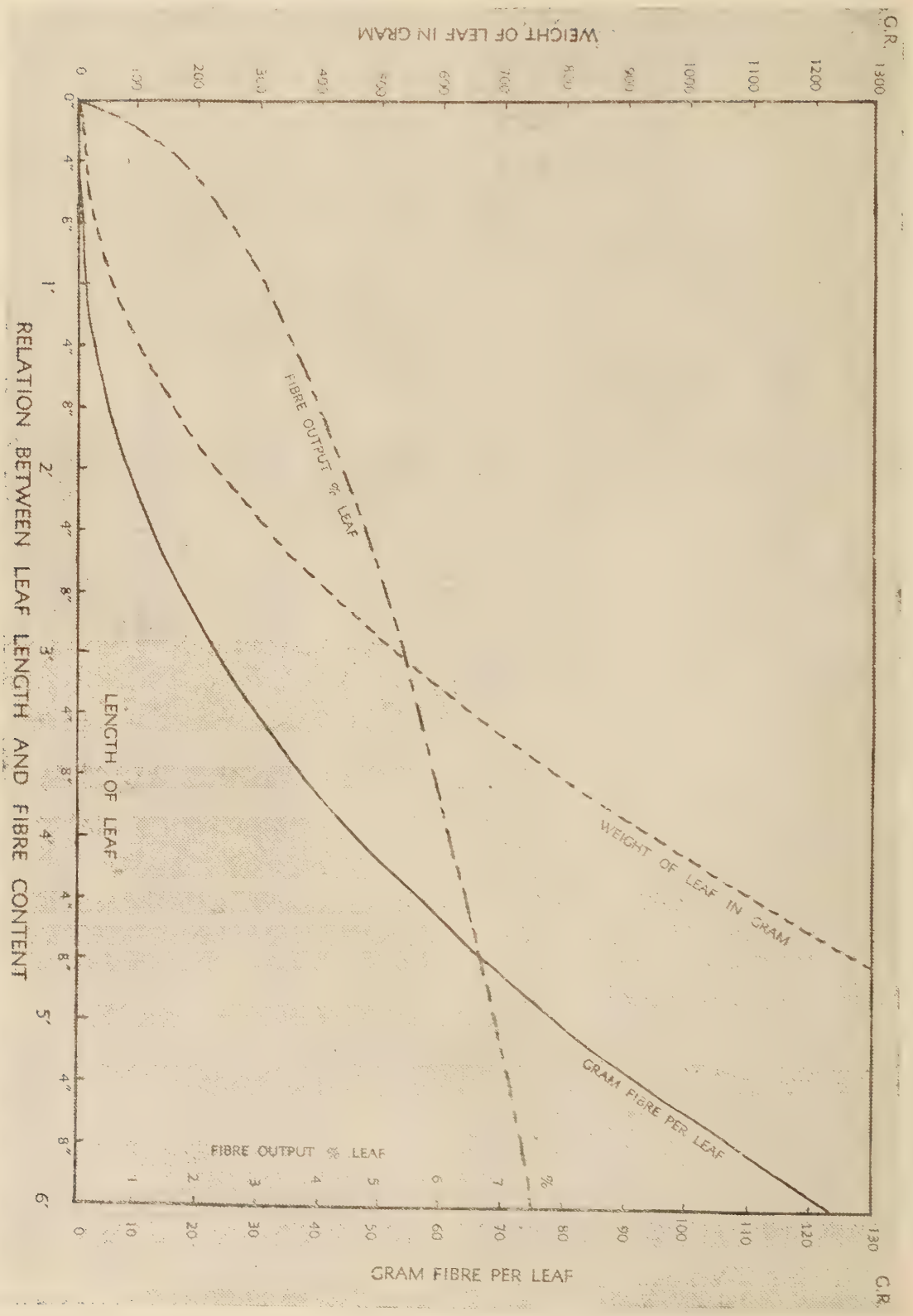
This gives the theoretical output from which the loss during decortication has to be subtracted. The actual output of line fibre will be about 70 per cent of this figure, depending on the losses. It has to be kept in mind, however, that formulæ (2) and (3) are less accurate than formula (1) as they are susceptible to various influences such as weather.

The above formulæ are not very practical for the planter, who may want to do some calculations of his own, as they contain squares and roots, and formula (1) a fractional power that can only be calculated with the aid of logarithms. For the convenience of the reader these formulæ have therefore been worked out in the form of tables, giving the length of the leaves in feet and inches. In the tables average values have been taken for the various parameters, 0.00035 for the K_1 of the fibre–length relationship, 0.0631 for the K_2 of the weight–length dependency and 0.555 for the output formula. As these parameters are dependent on the age of the plant, the actual figures in a particular case may be higher or lower, but their relationship (which is the thing that matters most for all practical purposes) will be the same.

In the accompanying diagram the dependence on the leaf length of fibre per leaf, weight of leaf and percentage output are shown graphically. The scale for the fibre is one-tenth and for the output one-hundredth of the scale for the weight of the leaves. The following table, the graph and the relationship between leaf length and fibre content as expressed in formula (1) can all be used for various agricultural and technical purposes and may be of importance for the calculation of the optimum population density of sisal. Longer leaves may in certain cases compensate for a smaller number of leaves per acre; if the same yield can be obtained by a smaller number of longer leaves, it would mean a saving of costs for labour for cutting and decortication. It is not the intention to give here an opinion on whether a higher or lower population density is desirable; this may depend on all kinds of factors, local and otherwise. But in dealing with this problem, the length of leaves and the amazing influence of the length on the amount of fibre should not be overlooked.

Length of Leaf		Grams of Fibre per Leaf	Weight of Leaf	Per cent Output
ft.	*in.*			
1	0	1·5	58·6	3·1
1	2	2·2	79·8	3·3
1	4	3·1	104·2	3·5
1	6	4·1	131·9	3·8
1	8	5·3	162·9	4·0
1	10	6·7	197·0	4·2
2	0	8·3	234·5	4·3
2	2	10·1	275·2	4·5
2	4	12·1	319·2	4·7
2	6	14·3	366·4	4·8
2	8	16·7	416·9	5·0
2	10	19·4	470·6	5·2
3	0	22·3	527·6	5·3
3	2	25·5	587·8	5·5
3	4	28·9	651·4	5·6
3	6	32·6	718·1	5·7
3	8	36·5	788·1	5·9
3	10	40·7	861·3	6·0
4	0	45·2	938·0	6·1
4	2	49·9	1,017·8	6·3
4	4	55·0	1,100·8	6·4
4	6	60·3	1,187·1	6·5
4	8	65·9	1,276·5	6·6
4	10	71·8	1,369·6	6·7
5	0	78·1	1,465·6	6·9
5	2	84·6	1,564·9	7·0
5	4	91·4	1,668·2	7·1
5	6	98·6	1,773·3	7·2
5	8	106·1	1,882·3	7·3
5	10	113·9	1,994·6	7·4
6	0	122·0	2,110·7	7·5

This formula can also be used for a quick estimate of the fibre production. Once one is used to thinking in numbers of leaves instead of tons of leaves, the average length of the leaves is all that matters in estimating the fibre yield. Although the formula was developed in Sumatra, one of its first applications was for estimating fibre yields of East Africa. A friend of the author, from Sumatra, who wanted to make a trip to East Africa in


RELATION BETWEEN LEAF LENGTH AND FIBRE CONTENT
LENGTH OF LEAF
WEIGHT OF LEAF IN GRAM
FIBRE OUTPUT % LEAF
GRAM FIBRE PER LEAF
C.R.

order to study the sisal industry here, asked for a simple method of estimating the approximate fibre yield of an African sisal field in comparison with a Sumatra field. The author gave him a table and a foot-rule.

It may be mentioned here that the author also tried to find another feature of the leaf which, in connexion with the length, would indicate the fibre content independent of the age of the plant. Various characteristics of the leaf were compared, including the cross sections at various places and the specific gravity. But unfortunately, although quite a lot of research has been done on the problem, all endeavours have failed.

A very interesting application of the length formula was made for the control of the decortication in the big sisal factories of Sumatra, factories with 20 or more coronas. Leaves from every field and cut were sampled and measured and their fibre content calculated. In this way it was known every day how much fibre had been introduced in the factory; by comparing this figure with the fibre actually produced, the decorticator losses were controlled. Later on, when all the waste was reclaimed and retted, the losses calculated by the length method were compared with the actual losses. Taken over periods of a fortnight, both figures agreed with sufficient accuracy.

The length formula can also be used to compare the output of various decorticators. One should always keep in mind that the fibre output of leaves can only be compared if the leaves have the same length; if not, the figures should be corrected by means of the above table or the formula (1).

BOOK REVIEWS

AN EXPERIMENT IN FORESTRY, by N. D. G. James, M.C., M.A., published by Basil Blackwell, Oxford, 1951, pp. 102, price 10s. 6d.

The author reviews the work carried out in the Forest Garden of the Royal Agricultural College, Cirencester, which was planted in 1903. Neglect during the two World Wars has affected the trees, but in spite of this, the Forest Garden provides experimental results of great value to foresters, both professional and amateur, in the United Kingdom. Its direct appeal to East Africa will be limited, but both farmers and foresters would be interested to see how much information was obtained from this small-scale forestry experiment of 10½ acres. The idea of a forest garden is probably new to East African farmers, but it would provide an interesting hobby and would also be a source of local information to the Forest Departments.

A NOTEBOOK OF TROPICAL AGRICULTURE, by R. Cecil Wood, 5th Edition, 1950, published by the Imperial College of Tropical Agriculture, Trinidad, British West Indies, pp. 147, price 7s. 6d.

No major alterations have been made in this notebook since its first edition in 1933, and the successive editions are a tribute to its usefulness. It contains a wealth of facts and information for farmers in the tropics, all severely practical, and after consulting it for 18 years, the reviewer feels competent to recommend it.

D.W.D.

AGRICULTURAL CO-OPERATION IN THE COMMONWEALTH, by Margaret Digby, published by Basil Blackwell, Oxford, 1951, pp. 172, price 15s.

The author describes briefly the rise and development of co-operative movements throughout the world, and then describes in turn co-operation in Great Britain and Eire, Canada, the West Indies, Australia, New Zealand, India and Pakistan, Ceylon, South-east Asia, the Mediterranean Islands, South Africa and Southern Rhodesia, and West, East, and Central Africa This comprehensive review will enable anyone interested in the subject to follow the trends in the Dominions and Colonies: its value in East Africa is that the experience gained and lessons learned in other parts of the Commonwealth are well worthy of study.

IS EAST AFRICA DRYING UP?

By Ivan R. Dale, Forest Department, Uganda

(*Received for publication on 11th December,* 1951)

Most of us, if asked this question and also what we considered the climate of the last 2,000 years to have been, would reply that the climate was probably not very dissimilar from that of this century and that there has been a tendency to drier conditions. Unfortunately there are few facts that can be adduced and the evidence has to be bolstered up with intelligent surmise.

Dr. E. J. Wayland was somewhat illuminating in his presidential address to the Uganda Society in 1935 (*vide* Vol. 3 of the Journal of that Society). He was of the opinion that major climatic trends in Euro-Asia were correlated with climatic changes in Africa. He also considered that there was possibly a climatic cycle of 640 years superimposed upon a general tendency over the last 7,000 years to drier conditions. This general tendency he considered to be so slight that it could be disregarded, but the superimposed cycle with the drier phases culminating about 1840, 1200, 560 and 80 B.C. has some supporting evidence. This evidence may be classified as firstly historical, secondly that deduced from tribal movements, and thirdly that from the forests. The assumption in the evidence for tribal movements is that large-scale migrations of pastoral peoples are more likely to occur after long periods of increasingly drier conditions. For the sake of clarity the first and second lines of evidence will be treated together.

Wayland considered that there was a long droughty period from 2200 to 1000 B.C., during which occurred the dispersal of the Aryans, the penetration of Egypt by the Shepherd Kings and the exodus of the Canaanites from Arabia. In Europe a very wet phase began in 850 B.C., resulting in the rise of lake levels, e.g. Lake Constance, and the accumulation of peat. Wayland considers the Nakuran epipluvial, when Lake Nakuru rose to 145 ft. above present levels, to represent this phase in East Africa. The next major climatic change was in the early centuries of the Christian era, when six widely separated lake basins in Asia show that very dry conditions prevailed. It is probable that the drying up of the grazing grounds initiated the irruption of the Huns into Western Asia and Europe. Mr. A. C. A. Wright has drawn my attention to the opinion of Sir Harry Johnston that the beginning of the present era (A.D. 1) is a fair approximation of the period of swarming of the Bantu tribes. These peoples are considered to have originated in French Equatoria. Having acquired goats and cattle from the North, they began moving towards the southern Sudan. The domestic fowl did not reach Egypt before the Persian invasion of 525 B.C., and as it has a common name amongst the Bantu peoples it is thought probable that they did not disperse widely until after the receipt of the fowl from the North. A minimum period of 300 years is given for this, and the general movement southwards to the Lakes is dated 200 years later.

The next authenticated movements occurred in the 13th century. That century was marked by the Mongolian and Tartar invasions of China and Europe from Central Asia. It is of interest that the rats also moved. They travelled more slowly however, and the resultant Black Death did not reach Western Europe until the 14th century. In East Africa, according to Sir Charles Elliot in *The East African Protectorate,* the Arabs moved south along the coast about 1200 A.D., founding Pate, Siu and Faza on Pate Island, Lamu, Malindi, Kilifi and Mombasa. E. B. Haddon, of Uganda and Cambridge, gave me his opinion that the Bahima people began migrating south along the line of the Western Rift about the same time. It would be pleasant to record that the Luo and Masai peoples had entered East Africa about 1200, but the former most probably entered Uganda and settled in Acholi about 1500 A.D., and Hollis records the probability that the Masai came into Kenya about the same time.

The first half of the 19th century should by the 640 year cycle theory have been very dry, and there is considerable evidence that it was. The Caspian Sea was very low in 1820, and about 1840 to 1850 according to tribal tradition Lake Rudolf sank to a very low level and Lake Naivasha was reduced to a puddle. The Nile should give some interesting records, but the observations of travellers only record that 1848, 1850, 1858, 1864, 1871 and 1877 as years of low Niles, and 1861, 1872, 1878, 1879, 1883, 1892 and 1895 as years of high. Con-

siderable tribal movements occurred about 1800. According to the records in Kisii boma the Avagusi (the Kisii) were driven south at the end of the 18th century by the Jaluo coming from the north-west and pushing south-east (J. R. L. MacDonald—a note in *The Bantu of North Kavirondo,* by Wegner). About 1850 the Turkana drove the Masai from the area west of Rudolf, and the Masai themselves reached their furthest south about 1830 when they were repulsed by the Wagogo and the Wahehe. Some years ago I dated the final evacuation of Gede in the first half of the 19th century on the basis of the tree growth on the ruins near the main entrance. The trees were almost entirely *Gyrocarpus jacquinii,* and owing to their rapid growth gave a false impression of antiquity. This dating has been confirmed by recent archæological research, and I opine that the wells dried up owing to drought.

Thirdly there is the evidence from the forests. This is more convincing when drawn from the warmer and wetter forests rather than from those on mountains and high lands. The former are more likely to have waxed and waned following climatic changes. The montaine forests probably did as well, but the evidence is less plain, partially because hills receive more deposition than plains, even if only from cloud and mist (e.g. Kasigau and some of the Kitui hills in Ukambani), and also because the rate of growth of Podo and also Cedar once past its youth, is very slow indeed. No evidence of forest expansion or retrogression is available from the Kenya coastal forests. In the slave-owning days the coastal strip was for the most part densely cultivated, and the bush resulting from the abolition of slavery and the abandonment of large areas is post 1850. The evidence from the wet evergreen forests is partly based on ecologists' findings that the trees *Parinari excelsa, Cynometra alexandri* and *Celtis soyauxii* where gregarious are the final stages in a succession of phases in the growth of forests. If this be true, and I believe it is, then the areas where these species predominate must be the oldest areas in those forests. (A point to be borne in mind when considering these forests is that probably the maximum age attained by any tree therein is no more than 600 years). Thus the parts of the Mabira forest in Mengo dominated by *Celtis soyauxii,* the areas dominated by *Parinari excelsa* in the Kalinzu forest in Ankole and in the Kibale forest in Toro, and those parts of the Budongo and Bugoma forests in Bunyoro, the Semliki forest in Toro and the Maramagambo forest in Kigezi, dominated by *Cynometra alexandri,* are, I consider, the oldest parts of the forests, and were the nuclei from which the forests spread. This spread is particularly well marked in the Mabira, Kibale and Budongo forests.

There are extensive areas of alluvium at the base of the southern slopes of the Imatong mountains, and through this alluvium the Aringa River runs in a gorge. Along the banks grows the mahogany, *Khaya grandifoliola,* the oldest trees of which may be 200 years old or more. The simplest explanation I have heard is that the alluvium was swept off the cultivated hills by heavy storms during a long dry period, and the stream quickly cut its way through. The mahogany trees give a rough idea of the date.

For evidence of recent spread of forests there is no need to limit oneself to the larger forests, though the evidence of an outward spread into tree savanna country is patent in many of them. In fact all the forests near the eastern wall of the Western Rift are increasing in size wherever they are able, and in north-west Acholi extensive closed woodland is appearing in places evacuated at the beginning of the century, owing to sleeping sickness. Young woodlands (of notably *Markhamia platycalyx, Phialodiscus unijugatus* and *Bridelia micrantha*) of certainly less than 100 years old are covering considerable areas of eastern Toro and of Mubende district. The forests in Mengo, north of Lake Victoria, are the subject of investigations into their powers of natural reproduction, and statistical analysis of the results stresses the fact that most of the forests are very young. The highland forests of the West are also very young in parts, particularly the northern end of Ruwenzori, where there are large areas of *Mæsa lanceolata.* The colonization of bare hills in the South Ankole forest reserve and of abandoned cultivation on Mt. Debasien by *Catha edulis* is impressive. Much of the woodland in Kigezi is known to be less than 60 years old. The Kenya evidence I have is small. Some of the glades in Kakamega forest are obviously closing in, and the colonization of grasslands on the Kinankop subsequent to the cessation of grass firing is remarkable.

By combining the evidence a picture of the past climate and the extent of the forests emerges. R. E. Moreau in his "Pleistocene Climatic Changes and the Distribution of Life

in East Africa" (*Journal of Ecology*, Vol. 21, No. 2, of 1933) considers that only in the last 12,000 years have conditions been favourable to race differentiation in the flora and fauna. If one accepts this figure the forests have been discontinuous since 10,000 B.C., and specific differences in the flora and fauna of the forests evolved subsequently. From 2000 to 1000 B.C. was probably dry, but in 850 B.C. a wet phase—the Nakuran epipluvial—set in. Drier conditions probably prevailed at the beginning of the Christian era, when the Bantu peoples moved south into East Africa. As these people had become cattle owners it can be assumed that the climate was dry and favourable to short grasses, suitable for grazing. In 1200 A.D. the evidence is fairly strong that the climate was definitely dry. The Bahima peoples travelled along the line of the western rift, grazing their herds on land which on the Uganda side at least is largely forested or covered with elephant grass. One can assume that the Arab invasion of the Coast was chiefly due to unfavourable living conditions in Arabia. For three centuries or more after 1200 I consider that probably very much wetter conditions prevailed resulting in a considerable outward spread of forests from what are now regarded as their oldest parts and also from riparian strips of forest in grasslands. From about 1600 onwards the probabilities are that the climate became drier, culminating in a very dry period in the first half of last century. In these $2\frac{1}{2}$ centuries the outward march of the forests would have been stopped, as the drier conditions would favour repression by grass fires. The sharp edges of some of the hghland forests may be due to this cause, and it seems to me very possible that much of the dead Cedar in the Highlands may have failed 100 to 150 years ago. Such catastrophes as the burning of the Cedar in the Burnt Forest on the Uasin Gishu can also be assigned to that time. Since 1850 the growth of the forest edges, the expansion of riparian forests especially in Mengo and Toro, and the startling growth of woodland in Acholi, Toro, Mubende and Ankole, which still goes on, leave no doubt in my mind of increasingly wet conditions.

The Minziro forests at the mouth of the Kagera River in Uganda and Tanganyika are probably exceptions to the general forest spread. These unique Podo forests swamp badly during the rains and reproduction must be difficult in such circumstances. The forests must regenerate and expand if at all during the drier phases of climatic cycles, not during the wet. The spread of tsetse fly becomes explicable if the country has been getting wetter. I assume that in the 17th and 18th centuries pastoralists had at least maintained their grazing lands by judicious firing. Rinderpest swept through East Africa in the eighties and decimated the herds. This disaster coupled with wetter conditions must have resulted in less efficient firing with the result that bush and scrub in many areas managed to get away, favouring the spread of the fly. At present there are large areas of savanna bush in Uganda, where the climate and soil are favourable to high forest. Protection against fire, the necessary seed trees, and young forest are there.

I conclude by giving the answer to the question in the title. East Africa is not drying up, and there is probably a tendency to wetter conditions. This may be countered with proof of increasing desiccation in some districts. The glib, but nevertheless true explanation is, I believe, that the desiccation is secondary or man-made, due to land misuse, usually consequent on overstocking, deforestation and overpopulation.

GRASS BURNING EXPERIMENTS ON THE MSIMA RIVER STOCK FARM, SOUTHERN HIGHLANDS, TANGANYIKA

By H. J. van Rensburg, Pasture Research Officer, Department of Veterinary Services, Tanganyika

(*Received for publication on 12th December,* 1951)

The stock farm with a total area of 5,000 acres lies approximately 20 miles north-east of Njombe in the Southern Highlands Province of Tanganyika Territory. It is situated on the Msima River which first joins the Ruhudji and Mnyera before it eventually reaches the Kilombero River.

Description of the Njombe Area and its Agricultural Possibilities

This is quoted from the 1932 Annual Report of the Department of Veterinary Science and Animal Husbandry as originally described by Mr. H. Wolfe, then Deputy Director of Agriculture, in the first report of the Land Development Commission, 1929:—

"This (the Njombe open grassland) is hilly grassland country, with solitary low trees widely scattered, and a dense forest growth in the more protected ravines and kloofs (pocket-like gorges). An occasional tall tree is seen in the rare small circles of forest growth which are maintained by the natives for some religious observance.

The tree growth, now almost entirely of secondary character, is believed to be the remnants of what was once a temperate rain forest, such as still exists about the eastern and western boundaries of the area (on the escarpment facing the Mahenge Plains and on the Livingstone Mountains bordering Lake Nyasa). The altitude, topography, humidity and character of soil, as well as the vegetation other than tree growth, combine to support this belief.

In the accepted classification of types of vegetation, therefore, the existing type is designated as 'Mountain Grassland'. The term 'open' is preferred for use in this report as being of clearer significance in the distinction between bare grassland (veld) and bush-grassland (bush-veld) which is envisaged by most agriculturists in Africa.

The change to the open grassland has been brought about by human agency. The area at no remote time supported a large population which has left the evidence of its density in the extensive stretches of hill-sides continuously and almost completely ridged for cultivation.

The population is now sparse, the decline having been brought about, according to native evidence, by wars and a greatly reduced birthrate. Wood cutting and annual grass burning over probably two or three centuries account for the disappearance of the forest and its succession by grassland.

Nowhere is the tree growth so pronounced as to interfere with the natural grazing. It is least sparse in the southern section of the area and almost entirely disappears in the northern. For the most part, looking horizonwards, the country has the appearance of bare grass-covered hills marked by small pockets of trees and the occasional grove of bamboos (indicating a native habitation) which breaks the rolling skyline.

The topography of the hills varies from gently rolling near the northern boundary to sharply broken in the south-west and about the larger water-courses, such as the Ruhudji, Ruhuhu and Ngongwa Rivers.

The area is intersected by numerous small streams which rise in the ravines and kloofs, and gather volume as they join to form the tributaries of the larger rivers. A watershed divide passes down the area near its centre almost throughout its length, the streams on the east flowing into the Ruhudji River (a tributary of the Kilombero River which joins the Rufiji thus finding an outlet to the Indian Ocean), those on the west being tributary to the Ruhuhu River which flows into Lake Nyasa.

Rock outcrops are uncommon and are confined almost entirely to the valleys of the larger rivers, where granitic boulders occur, and to the occasional belts of hills in which the decomposed granite is traversed by the harder undecomposed quartz, giving rise to superficial quartz rubble and, rarely, to small fragmentary outcrops of the rock.

Rainfall and Climate.—The rainfall is a seasonal one, opening in November or December and closing in April or May. The remainder of the year is rainless. The available records show a total rainfall of 42 and 50 inches in the two seasons, with the heaviest fall from December to March (29 and 46 inches respectively). The average annual fall is judged to be 43 inches in the central section, with an increase to 48 inches in the southern section, and a decrease to 38 in the northern.

The atmosphere, however, remains humid throughout the dry season. This is an area of low sunshine, high percentage of cloud and frequent mist. In the wet season, overcast skies are the rule. In the dry winter season days without 33 to 50 per cent of cloud are rare and overcast days are frequent.

The whole of the area lies at an altitude ranging from 5,800 to 6,300 feet except on the southern boundary, where there is a decline within a few miles to 5,500 feet. The frost line is judged to be at 5,900 feet. By this is meant that frost does not occur on the hills below approximately 5,900 feet; it occurs naturally at a lower altitude in the valley bottoms.

Hailstorms occur once or twice in the year during the hottest parts of the summer. The stones are small and the fall is quite localized.

A cold wind blows from the south-east throughout the dry season, but is never strong. Days without wind, or with a light breeze are frequent.

A brief general description of the climate of the area would be: a cool and moist atmosphere, a seasonal (summer and autumn) rainfall of approximately 42 inches, a cool to cold winter occasionally descending to freezing point with morning mists, and a warm, but not hot, summer with cool nights.

Soils.—The prevailing soil type is a red to reddish-brown clay loam of eluvial (residual) formation. (It will be referred to in this report as the red loam.) As with most residual soils, it possesses considerable depth and uniformity throughout its depth, the colour not changing, and the texture barely so with a slightly increasing percentage of clay downwards.

The red loam, with its local superficial variations, extends throughout the area and is broken only by the thin light grey soil of the belts of quartz hills. This soil (the latter) stands out by its distinctive feature of numerously dotted, stony anthills of the same light colour. Wherever the quartz rubble occurs the soil is not cultivable; elsewhere, it contains sufficient depth above the quartz for cultivation of shallow-rooted annual crops with heavy manuring. The soil is a poor one, containing approximately 80 per cent of sand (of which 65 per cent is coarse sand), declining to 70 per cent in the localities most favourable for its cultivation.

The red loam is of typically granitic origin, but may be classed as a relatively mature soil—that is, it has been much altered by influences of climate and vegetation, and the parent rock has no longer a substantial significance in its bearing upon the character or composition of the soil. The pink clay is a good sub-soil below a sufficient depth of soil, for it is one of the porous clays, providing a not unsatisfactory drainage and penetrated without difficulty by roots.

The red loam is not a fertile soil. Its parent rock is not a source of complete fertility and it is deficient in organic matter and nitrates. As may be expected, however, with its good texture and high moisture-retaining capacity, it responds very readily to manuring.

As granitic rocks have a low content of limestone, a mature soil derived from these may be expected to be deficient in lime. This is the case with the red loam, which is slightly acid. The acidity is sufficient to make of this area what is known in South Africa as 'sour veld', but only in a faint degree, the grasses being quite palatable to stock, except on the quartz hills and in the waterlogged valley bottoms, where the acidity is much more pronounced.

Because of what appears to be an unsatisfied need of oxidization, the red loam requires a year or two working before it will yield a satisfactory crop. The experience of the natives who cultivate this soil and the system of cultivation which they have adapted to this condition of 'rawness' and to the relative infertility of the soil, may be taken as a useful guide to the immediate needs of the red loam. The chief food crop is maize, but the maize is never planted in the first year. The soil is turned over and built into high and wide ridges, on which sweet potatoes are planted in the first year, without manure. This thoroughly aerates the soil and accelerates its oxidization. Some time after this crop is taken off, manure is placed in the rows and the rows and ridges are flattened over the manure. Maize is planted for three or four years on the flat, with a cultivation each year, and with manure in the first and second maize years. The yield is better in the second maize year than in the first.

Vegetation (*Economic*).—Apart from the sparse tree growth and the occasional bracken, the vegetation consists of an almost pure grass cover, from 1 foot to 4 feet in height. The grasses are almost entirely perennial and densely tufted. The short grass cover is confined entirely to the shallow soils of the quartz hills, and the change to the tall grasses as one passes out of the quartz belts into the red loam is striking. The covering is dense throughout. Amongst the tall grasses is a heavy undergrowth of fresh shoots in which actual growth is stopped for six weeks at the most in cold winters, and a shorter period in mild winters. Growth, however, is slow over a longer period. This indicates a soil of high moisture-holding capacity and a long free-from-frost growing period.

The best grazing areas are those in which pure stands of *Themeda triandra* (the well-known 'rooigrass' which dominates the high-veld of the Transvaal) occur most frequently and extensively. Such pure stands are rare in the northern section of the area; throughout the central section, from east to west, they are numerous and of excellent, dense growth; in the southern section they occur less frequently but in equally good growth. Though these pure stands of Themeda are far from being so extensive, individually, as the great areas covered by them in South Africa, they are believed to be equal in the quality of the grass, and superior in the quantity of grazing afforded per acre. The growth through the stand, with the undergrowth, is denser, and a heavier rainfall, with a longer frost-free growing period, provides later grazing into the winter, and earlier spring grazing.

Agricultural Possibilities.—Omitting for the moment the problem of transport, and regarding purely the natural conditions, the type of agriculture to which this area may be taken as suited is that known as mixed farming (the raising of livestock associated with the growing of both fodder and cash crops).

It is pre-eminently a cattle country. The grazing in general may be classed as good for cattle; in the pure stands of Themeda and in those mixed stands in which Themeda dominates, with *Hyparrhenia cymbaria* and *Panicum maximum* prominent, it is excellent. The grass cover being almost entirely perennial, to improve upon its existing condition for grazing, the grasses should be kept low and and not allowed to go to seed. Alternate paddocking will be necessary to preserve the crowns of the roots and allowing tillering when the farm approaches the fully-stocked condition. Under such careful management, the carrying capacity of the grazing is estimated at three and a half acres per head of cattle on the red loam over the whole area except in the northern section, there it is reduced to five acres per head. The carrying capacity may naturally be increased with supplementary feeding. In the dry winter season, feeding is not necessary to maintain life, but certainly condition, during a period which will vary with the extent to which the farm is stocked: with 50 per cent stocking, the

period is estimated at two months in the central and southern sections and three months in the northern. Farms traversed by wide river valleys will have the advantage of succulent, though somewhat sour, grass pasture in the dry months, except in years of severe frost in these bottoms. Hay cutting on the flatter stretches, for winter feeding, may be done by ox-drawn mower without difficulty. Regular salt lick will be necessary for maintaining condition in the dry season (it assists the digestibility of the dry grasses) and may with advantage be given throughout the year. A source of salt close at hand is being investigated; other sources exist in the Territory, but transport from these is at present costly.

It is believed that sheep will do well on the grazing, associated with cattle, the latter keeping the grasses down for the use of the former. Natural short grass exists on the quartz hills, but the quality is believed to be inferior and it dries up very early in the winter. The grazing capacity for sheep is estimated at one head per acre without supplementary feeding under careful range management.

The judgment expressed in the preceding paragraphs are conditional upon two factors: freedom from serious disease, and the use of the most suitable types of cattle and sheep. A Government experimental stock farm is likely to be established in the area to determine these factors as well as other problems connected with stock rearing such as range management. The value of this work for land settlement will be considerable, and it is likely to be enhanced when the suitable types of cattle and sheep are determined, by the breeding of stud stock for sale to the settlers, as is done by the Government in South Africa. For reasons given elsewhere (paragraph 46 of the Land Development Survey Report) the most important (for the present only immediate) problem is the most suitable type of sheep for wool production, and the work of the Government farm for the first few years will probably be concentrated chiefly on this problem, including inimical factors, such as disease.

In contrast to the natural conditions, which permit of a wide variety of products, the existing economic conditions will very strictly limit these. Here are all the elements of a good and stable mixed farming, such as has been so successful under closely similar conditions in South Africa, except the essential one of cheap transport. It may be regarded definitely that no branch of farming will pay under present circumstance of a remote railway, except the possible one of wool production, the suitability of which for the area remains to be proved. The average distance to the Central Railway approaches 320 miles. The market for wool is likely to remain at its present level for some years, but it will naturally be most profitable, and possibly necessary, to produce the best wool of which the conditions and the individual management are capable; not only because of the higher gross revenue in itself, but also because of a lower relative cost of transport.

It is doubtful if inferior grades of wool will be marketed at a profit. The problem is one of the classes of wool, type of sheep, breeding; indeed a number of factors which require expert examination."

History of the Stock Farm

The great open grassland country of Njombe appeared to be excellent for stock and so it was decided to start this farm which it was considered would be developed as a convenient source from which graded-up stock could be obtained by settlers and for general experiments in connexion with livestock.

Work on the farm was commenced in 1929 and at the time it appeared probable that a railway would soon be laid through or near the Southern Highlands. It was envisaged to introduce cattle, pigs and poultry with a view to fitting these into a scheme of profitable mixed farming, with dairying and bacon manufacture predominant. Wool production was also to be investigated.

East Coast Fever exists in enzootic form and it was estimated in 1932 that the calf mortality throughout the area probably averaged 50 per cent. It was considered that if an area cannot be kept practically free from East Coast Fever the best thing to do is to encourage this condition of enzooticity and to see that all calves pass through their first and most severe attack while they are very young and well looked after.

At one time it seemed probable that the policy of the settlers in the Southern Highlands would be for a number of them to take up a large block of land with access to a railway and to free the whole occupied area from East Coast Fever by dipping. In that case an important function of the stock farm would be the production of high-class bulls for issue to these settlers. Then came the disastrous period of world-wide agricultural depression, and this policy became financially impracticable.

It was then decided that it was necessary (*a*) to attain exact knowledge of the potentialities of the area for both beef and dairy cattle though it was evident that more detailed information was necessary of range management, soils, vegetation and the effect of grazing and burning; (*b*) a thorough investigation of the possibilities of utilizing these grasslands for the production of high-class wool. As soon as it was certain that a railway would not be built through the Southern Highlands at an early date the Department considered that the most economic livestock product which could be produced in these large tracts of well-watered grassland is wool of superior quality.

In 1931 funds were made available from the Colonial Development Scheme for investigat-

ing the possibilities of wool production and the main object of the farm became the investigation of the possibility of farming woolled sheep in the area. It was realized, however, that the nature of the grazing was such that sheep would be most likely to succeed if farmed in conjunction with cattle; the cattle to be used mainly as necessary adjuncts to sheep farming, though it was considered that investigations as to their greatest possible economic use, apart from sheep, should not be thereby precluded.

Romney Marsh sheep from England and from Kenya as well as Merinos from South Africa were introduced. The Merinos seemed to do better than the Romneys but a great deal of trouble was experienced with suspected plant poisoning, nodular worm and other intestinal parasites which seemed to thrive in the moist, cool Njombe climate with no severe winter frost. Regular dosing with worm mixtures was practiced while the sheep were kept from the low-lying damp land and only in the driest months were they allowed on the vlei land which had been cultivated and planted with rye grass.

The conclusion was forced upon the officers concerned with these investigations that they were dealing with a vicious circle of undernutrition and parasite infestation. The pasture seemed deficient in some essential ingredients and the undernourishment favoured worm-establishment in the bowels, and this, in turn, accentuated undernourishment.

It was then decided to make a general survey of the farm from a nutrition point of view and the results revealed that—

(i) the red loam covering the major portion of the area is generally deficient in plant foods;

(ii) that the pastures of the Njombe area are generally deficient in minerals, particularly phosphate, potash and lime. The crude protein content is low whilst fibre is high. The green grass contained nearly twice the protein and soluble ash contents of the matured dried grass though even so, it is still very deficient in protein and minerals when compared with normal European pasture grasses. Samples of oats, beans and linseed obtained from the stock farm were analysed and they all showed a protein deficiency whilst the phophate and lime contents were below normal samples;

(iii) blood analyses carried out indicated that the inorganic blood phosphorous of the stock was well below the optimum for bovines and confirms the results of analyses of the soils and herbage. The phosphate level is sufficient to allow slow growth, late reproduction, and weak lactation, but not high enough to allow for anything like maximum production;

(iv) the stock on the farm seemed to have a craving for salt and showed a tendency to eat soil from one point on the farm. On analysis this was found to contain a small percentage of chloride.

Pasture Investigations

The importance of the vegetation cover and the need to find the most efficient methods of utilizing and supplementing it became one of the outstanding problems necessitating various aspects to be investigated in more detail.

Natural Pastures.—It was found that a very high proporton of the plants forming the local vegetal cover consisted of perennial herbs and only about one-quarter of the total number were grasses. Some were forest species of shrubs and trees which strongly supports the hypothesis that the area was once under forest.

The dominant grasses on the hilltops and slopes were *Themeda triandra* (red oat grass), *Loudetia simplex* and *Hyparrhenia nyassæ* (thatching grass); and these occurred in various proportions together with a large number of other species. In the young growing stage the grazing seems palatable and is relished by stock but if allowed to mature it becomes coarse, unpalatable, fibrous and of low digestibility.

Close grazing seems to improve the feeding value of the pasture but at the same time may render it more dangerous as a source of worms. It was evident very early on during the experimental programme that fire would probably be an important factor in the management of natural pastures and that apart from the control of undesirable species burning stimulates early growth of nutritious herbage to replace the old dead grass with very poor feeding value. Furthermore, it assists in the destruction of parasites. Conditions conducive to annual grass fires and the dominance of the grass association largely brought about by burning prevents the plant succession from proceeding to its natural climax of evergreen bush and forest.

The vlei lands afford a fair quantity of green feed during the early dry season months, particularly if burnt early in the dry season.

This natural pasture shows a great similarity to the South African sour veld where the stock carrying capacity is largely dependant upon the amount of winter feed that can be produced.

It was considered that the value in October and November of vlei land burnt in June or July is very great and largely determines the value of the whole farm and that no more stock should be put on to the farm than can be carried during October and November by the burnt vlei land unless the balance is made up with preserved winter feed. Furthermore, that an equivalent amount of established pasture such as *Paspalum dilatatum* should be provided for the two cold months of August and September. A safe rule regarding the natural pastures seemed to be that the grass that cannot be grazed should be burnt every second year.

The following observations were made from the results of an experiment on the effects of different intensities of grazing with stock rates of an ox to six acres, an ox to four acres and an ox to two acres. Staples' conclusions are quoted verbatim:—

"Close grazing to prevent the too rapid maturing of the herbage, would thus appear to be an effective method of improving the grazing during the latter half of the wet season and the early dry season months. With close grazing, too, the natural hillside pastures were found to be able to fatten mature native or grade oxen wonderfully well in the growing season, but were not sufficient to maintain them in even reasonable condition during the late dry season months.

These tests on grazing at different intensities indicate that:—

(1) The Njombe mountain grasslands have a high degree of stability and are not readily affected by close grazing (the same conclusions in regard to burning were arrived at in the burning experiment).

(2) Better results, as regards the condition which the stock put on, were obtained from intensive grazing than from light grazing, apparently due to the higher nutritive qualities of the herbage during the late wet season and early dry season in the more closely grazed pastures.

(3) Little difference in palatability appears to exist in the various grasses, hence the disadvantages of selective grazing (by encouraging the coarser species) is not a marked feature associated with the grazing of these pastures.

(4) Intensive grazing over a period of years does not appear to result in a rapid deterioration of the vegetal cover, except along footpaths, where it would appear that soil erosion could be readily stopped by easily and cheaply constructed contour ridges. Intensive grazing, also, does away with the need for frequent firing of the herbage to maintain its palatability and nutritive qualities and will greatly reduce the intensity of the fire if the pasture is burnt.

(5) Apart from the shrubby tree, *Parinarium curatillifolium* which is browsed slightly and also affords useful fuel, intensive grazing in this experiment has not resulted in any serious increase of undesirable weed plants."

Established Pastures.—The very low level of soil fertility proved to be a great disadvantage in the establishment of pasture grasses and satisfactory grazing, hay and fodder yields were only obtained from fields which had received heavy dressings of farmyard manure or compost. It is also mainly due to this factor that only a relatively small proportion of the large number of pasture grasses and fodder crops which were established proved satisfactory and were able to survive without intensive management and constant care.

It was anticipated that established pastures would provide good quality grazing from July to September and so bridge the period between the time that the cattle are taken off the natural hillside pastures and before they are put on the vlei grazing with supplementary hay during the last three months of the year.

Considerable difficulty was experienced at first in establishing *Paspalum dilatatum* especially when it was propagated from roots and planted on untreated soil. The plants were small and growth stunted while large bare patches developed. When established under more favourable conditions with heavy manuring and composting, it did well and produced excellent grazing much superior to the natural hillside pasture, chiefly during the early dry season months and it seemed to stand up well to close grazing. Furthermore, in addition to remaining green for a relatively long period it also produces green growth before the natural hillside pastures.

It was considered advisable to establish *Paspalum dilatatum* together with Rhodes grass by using a relatively high seeding rate of about 20 lb. per acre to encourage a better soil cover. *Paspalum virgatum* also seemed a promising grass for the area.

Rhodes grass (*Chloris gayana*), similarly to *Paspalum dilatatum* did well under cultivation on well-manured fields and provided excellent early dry season grazing, useful crops of hay, and fairly good yields of seed. A strain collected from the Iringa district seemed to have outstanding drought resistant properties and remained green over a relatively long period.

Star grass (*Cynodon plectostachyum*) also provided palatable grazing but showed a tendency to dry off rather early and was therefore considered to be best suited as summer

pasture. It was, however, doing better on more fertile soil and produced a superior pasture that could stand up to close grazing. *Cynodon dactylon* also seems a promising pasture grass. Both these species have to be established from roots.

On the whole the levels of soil fertility on the farm are too low for Kikuyu grass (*Pennisetum clandestinum*). Growth was poor unless the fields were very heavily manured. On heavily manured land it provided palatable grazing of superior quality; it was much sought after by the stock and was very closely grazed during the dry season. It seemed to be doing better in other parts of the district on humus-rich soils.

With heavy manuring Elephant grass (*Pennisetum purpurem*) made good growth and remained green until well after the end of the rains producing useful green fodder for soilage. It could be established from roots and cuttings.

Italian rye grass, perennial rye grass, cocksfoot and tall fescue were also planted and of these Italian rye grass on heavily manured vlei land did moderately well.

In addition to these introductions 27 indigenous species, considered most promising for cultivation purposes were also established but none of these produced outstanding results.

Annual Crops.—Barley, oats, wheat, maize and buckwheat, treated with heavy dressings of farmyard manure, produced useful crops for grazings and fodder. Edible canna and rib grass (*Plantago lanceolata*) were disappointing.

Legumes.—Vetch gave the most satisfactory results of all the legumes tried and under favourable circumstances with heavy manuring produced hay yields estimated at two to three tons per acre. Peas, *Serradella* and sweet lupins established under similar conditions were also promising. *Stylosanthes guyanensis* made good growth and kudzu vine seemed promising though it was very slow to get established.

Other legumes established for trial were:—

Pigeon pea (*Cajanus indicus*).
Korean Lespedeza.
Stylosanthes Bojeri.
Stylosanthes mucronata.
Trifolium hibridum.
Red clover.
White clover.
Subteranean clover.
Melilotus alba..
Lucerne (Medicago sativa) "Hunter's River".
Lucerne (Medicago sativa) "Chinese".
Lucerne (Medicago sativa) "Provence".
Lucerne (Medicago sativa) "gruum".
Lucerne (Medicago sativa) "mureia".
Lucerne (Medicago sativa) "africana".
Lucerne (Medicago sativa) "cossack".

Afforestation

Most of the trees established on the farm have grown satisfactorily and they have made a very marked difference to the farm in providing suitable windbreaks, timber and fuel for the station. Species of Eucalyptus, Cupressus, Acacia (wattles), Grevillea, Jacaranda and others have all done well. An extensive afforestation programme could fit in admirably and is essential for a mixed farming venture in this area.

Stock

Great difficulty was experienced with Romney Marsh and Merino sheep, apparently due to intestinal parasites, under-nutrition and suspected plant poisoning. On the whole their condition was most unsatisfactory.

The cattle brought on to the farm included native Zebu oxen, Friesian, Ayrshire, Afrikander and Indian Krishna Valley heifers.

All reports on the cattle between January and September during the years 1932 to 1938 were most favourable and their condition, particularly those of the males and dry cows was generally described as: "prime, splendid, excellent, good or extremely good". During the remainder of the year, October to December, this general description seemed to alter to: "reasonable, almost satisfactory, not so good, and fair to poor"; especially when referring to cows suckling their calves.

The general observation was made that: oxen can fatten to a high degree on this grassland and young stock can grow satisfactorily, if somewhat slowly. Cows yielding just enough milk for their calves can maintain condition while those giving more than this minimum draw on their systems and go to pieces badly.

It was considered that the animals should be grazed on the natural hillside pastures from January to July and on *Paspalum dilatatum*, Rhodes grass and other established pastures from July to September. Between October and December they should be grazed on vlei

pastures burnt about June, while liberal supplies of hay supplemented by concentrates and minerals should be fed during the dry season as required, particularly to cows suckling calves and to young growing stock. Fluke infestation was a serious factor and was partly responsible for the loss of condition of cattle in the dry season, while worm infestation is probably more serious than was realized.

Annual or periodic fires sweeping through these unstocked or lightly grazed grassland areas seemed to have little or no effect on the vegetation especially with regards to the frequency of dominant grass species such as *Themeda triandra, Loudetia simplex* and *Hyparrhenia nyassæ*. It was, however, assumed that elimination of burning either as the result of close grazing or in protected areas might bring about an increase in bush species. The objects of laying out a series of grass burning experiments were therefore in the first instance to find out the effects of burning on the quality of the pasture and secondly to determine the optimum frequency and best time of the year for burning to be carried out

It was evident that, for the time being, it would be impossible to eliminate burning except perhaps with closer settlement and heavy stocking. It was considered desirable to burn so as to obtain palatable young grass and to destroy parasites.

One of the most outstanding features of the experiment is the rapidity with which differences in the condition of the vegetation on the plots were brought about by the different treatments and the small degree of subsequent change noticeable over a large number of years. Observations made and recorded by Staples in the 1933 and 1937 Departmental Annual reports for the larger part still seem to hold good and the bulk of the descriptions could be quoted verbatim to describe the condition of most of the plots at present; thus bearing out and confirming the significance of deductions made earlier in connexion with the high degree of stability of the vegetation in the Njombe mountain grassland.

The grass burning experiment planned allowed for the following treatments and a list of the operations carried out is also given.

Plot	Treatment	Details of Operations
1a, 1b, 1c	Burned in October every year.	Burned every year in October between 1931 and 1951, except in 1946 when no record was kept.
2a, 2b, 2c	Burned in October every second year.	Burned October 1931, 1933, 1935, 1937, 1939-1941, 1943, 1945, 1947 and 1950. (Burning in 1949 was omitted in error.)
3a, 3b, 3c	Burned in October every third year.	Burned October 1931, 1934, 1937, 1940, 1944, 1947 and 1950. (Burning in 1943 omitted in error.)
4a, 4b, 4c	Burned in 1931, then cultivated and left.	Burned October 1931, cultivated in December, 1931 and protected from grazing.
5a, 5b, 5c	Burned in October, 1931 and mown in May every year.	Burned October, 1931 and mown every year in May between 1932 and 1951.
6a, 6b, 6c	Burned in December every second year.	Burned December, 1931, 1933, 1935, 1936, 1938, 1940, 1942, 1944, 1946, 1948 and 1950. (1936 burning in error.)
7a, 7b, 7c	Burned in February every second year.	Burned in February every second year between 1932 and 1948. (Plot not burnt in 1950.)
8a, 8b, 8c	Burned in May every second year.	Burned in May, 1932, 1934, 1936, 1938, 1940, 1942, 1944, 1947, 1949, 1951. (Plot not burnt in 1946.)
9a, 9b, 9c	Burned in April every third year.	Burned in April, 1933, 1936, 1938, 1941, 1944 1948 and 1951. (Burnt in error in 1936 and not burnt in 1947.)
Control	Protected from burning and grazing.	Protected from burning and grazing between 1927 and 1951.
Fire-break, 15 yards wide around the whole area.	Burned in June every year.	Burned in June every year between 1931 and 1951.

Prior to the commencement of the experiment in 1931, the whole area was last burnt in May, 1927, hence the control area has neither been burnt nor grazed since that date.

Description of the Experimental Area

The burning plots, of which there are 27, are 100 yards long, by 25 yards wide and the control plot to be protected from grazing and burning is approximately 12 acres.

The general appearance of the area in 1933 was described as remarkably uniform especially in regard to the incidence of the dominant grasses. The vegetation consisted of a grassland association of *Loudetia simplex, Hyparrhenia nyassæ* and other species, with occasional clumps of pioneer evergreen forest species growing around ant mounds. The dominant species were perennials with a tufty habit of growth; the leafage averaged 12 to 18 inches and the flower stalks 2 to 3 feet. A large number of other grasses also occurred. These are listed in an appendix to the report.

Observations Made on the Experimental Area

Control Plot with Protection from Grazing and Burning.—The general appearance of the control plot seems to resemble very closely the condition described by Staples in 1933 and again in 1937. From a pasture utilization point of view it presents a most unattractive picture. The herbage has lost all its vigour and a mass of dead grass that seems to smother any new growth remains. This "stagnant" appearance due to deterioration from over-protection forms a marked contrast to the vigorous growth on the plots where the grass is being burnt during the late dry season or early growing season. Some of the smaller grasses such as *Eragrostis chalcantha* seem to have been crowded out entirely. *Loudetia simplex* seems to remain the dominant grass though large tussocks of *Elyoneurus argenteus Lasirurus* sp. aff., *L. Maitlandii,* and *Trachypogon plumosus* also occur.

The mat of accumulated dry grass seems to remain on the surface of the soil though the upper few inches especially around the large decaying grass tussocks feels loose and friable. It seems that a fire in this grassland type after a relatively long period of protection would cause severe damage to the roots of the grasses and that it would expose a large proportion of the soil surface to the agencies of the weather; thus probably undoing any good that might have resulted from the protection received.

The clumps of evergreen shrubs around the termitaria appear to have increased to a certain extent both in circumference, height and density though on the whole the rate of increase and development seems to be rather slow so that it would require an exceedingly long period before the climax stage is reached.

The plots which were cultivated after having been burnt in 1931 with subsequent protection from grazing and burning are now very similar in appearance to the control plot with a dense cover of old grass and a heavy layer of mulch on the surface of the soil particularly in the vicinity of a large bush clump. *Loudetia simplex* seems to be the dominant grass; *Themeda triandra* and *Melinis minutiflora* occur occasionally and there are a few conspicuously large bunches of *Lasirurus* sp. aff. *L. Maitlandii. Cassia mimosoides, Helichrysum* sp. and *Vernonia* sp. occur occasionally throughout the plots.

The Effects of Burning in June Every Year.—Dicotyledonous herbaceous plants such as *Gnidia, Clerodendron, Indigofera* and *Cassia* are very conspicuous and produce vigorous green growth about 15 inches high, long before the grasses begin to grow. These plants, most of which have a well-developed and deep root system seem to take advantage of the lack of competition during the period while the grasses are dormant and develop to their maximum before the grasses start to grow after the early rains. The ground cover seems quite reasonable compared with the other plots though the soil remains exposed for a long period to the sun and wind before the early showers commence.

The Effects of Burning in October Every Year, Every Second Year and Every Third Year.—On the plots where the grass is being burnt in October annually or once in two years a dense grass cover and vigorous leafy growth have been maintained. Abundant flowering heads, mainly of *Loudetia simplex,* about 2 to 2½ feet high have been produced. *Themeda triandra* occurs occasionally and is locally abundant around termitaria. Herbaceous plants, although present in considerable numbers are not conspicuous. These include *Vernonia, Helichrysum, Cassia, Ipomœa, Acalypha, Clerodendron* and five plants of Parinarium, 2 to 4 feet high.

On the whole, the plots which are being burnt in October every second year, seem to be in the best condition and are outstanding

amongst all the plots for leaf growth and uniformity.

The grass on the plots burnt in October every third year is more tussocky and it appears that a considerable amount of damage has been caused to the smaller grasses, probably due to fierce burning of the dry grass accumulated over a period of three years or due to competition for light and subsequent crowding out of the smaller species. The cover is comparatively poor while there are very few flowering heads of *Loudetia simplex* and *Hyparrhenia nyassæ*. *Cassia mimosoides* and other herbaceous plants are most conspicuous.

The Effects of Burning in December Every Second Year.—The grass growth seems rather stunted though the ground cover is fairly good. There is a very marked reduction of flowering culms with very few heads of *Loudetia simplex*. A number of other grasses such as *Hyparrhenia nyassæ, Themeda triandra, Hyparrhenia cymbaria, Melinis minutiflora,* and *Brachiaria* sp. occur occasionally and locally. On the whole Dicotyledonous growth is not conspicuous.

The Effects of Burning in February and May Every Second Year and in April Every Third Year.—The general appearance of these plots is most undesirable from a pasture usage point of view. The grasses seem to have suffered most severely from these treatments. The leaf growth is very poor and stunted, the vegetal cover very sparse and the soil surface seems hard and baked.

There is a vigorous and most conspicuous growth of Dicotyledonous weeds such as *Cassia, Tephrosia, Acalypha Senecio, Vernonia* and *Helychrysum.*

The Effects of Cutting the Grass in May Every Year.—The plots have a most satisfactory appearance; the vegetal cover is even and excellent throughout, comparing very favourably with the other plots. *Loudetia simplex* seems to be still the dominant grass.

Cassia mimosoides, Tephrosia and other dicotyledons occur but on the whole they are inconspicuous and small.

General Observation

In plots where burning is done periodically (every second or third year) there appears to be considerable seasonal changes in density of growth and frequency of flowering culms produced. Observations made at any one stage may therefore be misleading. To a certain extent it would depend upon the period that had lapsed since the previous burning, the fierceness of that burn and upon weather conditions since the burning was done.

It should, however, be borne in mind that livestock have been excluded from these plots and that grazing would have a considerable effect upon the nature of the herbage and that this in turn would influence the effect of fire on the sward, the fierceness of the burn and the frequency that burning would be possible. Depending upon the intensity of the grazing there would not be the same accumulation of dry grass available to produce a regular burn. Furthermore, the effect of grazing on plots burnt at different times of the year might also bring about considerable differences in the vegetal cover both as regards density and botanical composition.

Grass Burning to Control Parinarium curatellæfolia.—It seemed that the elimination of burning either by intentional exclusion of fire from grassland or by the elimination of fire due to constant grazing tends to cause an increase in *Parinarium curatellæfolium.* It was therefore decided to lay out a further series of experimental plots for further observations to be carried out and four small plots were demarcated in 1937 in an area where *Parinarium* occurred frequently. The treatments prescribed are as follows:—

D1.—Burn October every year.

D2.—Burn October every second year.

D3.—Control (no burning).

D4.—Burn March every second year.

The treatments received up to date are as follows:—

D1.—Burnt October every year since 1937 except in 1949 when it was not burnt.

D2.—Burnt October, 1937, 1939, 1941, 1943, 1946, 1948 and 1951. It was not burnt in 1945 and in 1950.

D4.—Burnt March, 1938, 1940, 1942, 1944, 1946, 1948 and (in error) in October, 1950, instead of March.

The three plots which are being burnt have a fairly good grass cover though the leaf growth in all cases is rather short and stunted with relatively few flowering culms of *Themeda triandra* and *Loudetia simplex.* The

Parinarium occurs in open growth with grass growing right up to their stems and there is little apparent encroachment of other dicotyledonous plants or excessive thickening up of the *Parinarium*, except in plot No. 2 where there is a dense clump of bush near a large termitarium with *Gymnosporia, Vitex, Harrisonia* and other woody plants. A number of self-sown wattle seedlings about 3 feet high occur in plot No. 4.

The control plot has a dense mat of decomposing grass consisting of *Themeda triandra. Loudetia simplex, Hyparrhenia nyassæ, Melinis minutiflora* and other species. *Parinarium* seems to have thickened up considerably and underneath the bush clumps is a dense layer of humus with a good soil texture. Seedlings of *Cussonia, Chrysophyllum* and *Myrsine* as well as one large *Mimusops* tree occur.

Summary of Results Obtained So Far and General Discussion

In many respects there is little to add to some of the conclusions arrived at by Staples, French, Hornby and other workers between 1931 and 1937 and portions of the summaries of their reports are quoted more or less verbatim.

Much difficulty was experienced in keeping sheep under Njombe Mountain grassland conditions due to under-nutrition, intestinal parasites and suspected plant poisoning.

A general nutrition survey of the farm revealed that the main soil type in the area is deficient in plant foods, that the pastures were low in essential minerals and protein and that the inorganic blood phosphorus of the stock was well below optimum.

Rhodes grass, star grass, Kikuyu grass, elephant grass, a few other grass species, and annual crops such as barley, oats, maize, buckwheat and vetch, produced satisfactory results on cultivated and heavily-manured land.

It seemed best to graze the stock on the natural hillside pastures between January and July; on established pastures between July and October, and on vlei land which is burnt in June for the rest of the year. During the dry season they should also be given hay, silage, and other supplementary feeds, particularly in the case of cows feeding their calves.

Better results as regards the condition which the stock put on were obtained from intensive grazings than from light grazing, apparently due to the higher nutritive qualities of the herbage during the late wet season and early dry season in the more closely grazed pastures.

Intensive grazing over a period of years does not appear to result in a rapid deterioration of the vegetal cover, except along footpaths. It also does away with the need for frequent burning of the herbage to maintain its palatability and nutritive qualities and will greatly reduce the intensity of the fire if the pasture is burnt.

Apart from the shrubby tree *Parinarium curatellæfolium* which is browsed slightly and used for fuel, intensive grazing has not resulted in any serious increase of undesirable weed plants.

Complete protection from burning and grazing for a period of 24 years has rendered the pasture most unattractive from a grazier's point of view, resulting in an accumulation of dead herbage which seems to smother fresh growth while causing deterioration to the crowns of the grasses. Burning of areas protected for a number of years cause much damage to the vegetal cover by killing off the plant tussocks and leaving large bare spaces.

It seems essential that pastures which are not mown or closely grazed should be burnt periodically to maintain the palatability and nutritive properties of the herbage.

The optimum time to burn seems to be during the dry season and the plots burnt in October every year or every second year seem to produce the densest, tallest and most vigorous grass growth. Depending upon the intensity of grazing, however, the frequency of burning and the fierceness of the fire would normally be determined by the amount of herbage left ungrazed by the stock.

Burning during the dry season, tends to suppress the encroachment of woody vegetation and to keep the sward free from weeds.

Burning during the rainy season (February, April and May) seems to reduce the density of the grasses while it encourages certain coarse tussocky grasses.

Burning during the rainy season also seems to induce rapid and vigorous growth of dicotyledonous species such as *Gnidia, Clerodendron, Indigofera,* and *Cassia mimosoides.*

The cover, density and vigour of growth of the grasses in the plots burnt in June and

December appear to be somewhere about halfway between the good results obtained from the October burns and the poor results from the plots burnt during the rainy season.

Cutting seems to have the most desirable effect upon the vegetation. Growth and the surface area covered by the plants seem to increase in contrast to the burning plots where a tussocky growth develops while the ground cover deteriorates.

This mountain grassland appears to be an unusually stable type and is not easily affected by close grazing or burning.

Although certain high-priced plantation and field crops such as tea, coffee, wattles and pyrethrum can be grown in certain selected areas, a very important part of the economy of this area will have to be built up upon mixed farming; particularly in view of the low inherent fertility of the soil and the need for livestock to improve its productivity as well as supplying marketable animal products.

REFERENCE

French, M. H., Staples, R. R., and Hornby, H. E.—Reports given in the Annual Reports of the Department of Veterinary Science and Animal Husbandry, Mpwapwa, 1932–1937.

REVIEW

Economie Forestiere Nord-Africaine—By P. Boudy (1948)—(*Editions Larosse, Paris (Ve)*, 4710 *francs*)

This monumental work, totalling 1,564 pages, is in two volumes of which the second is in two parts. M. Boudy, the author, has served and lately was Inspecteur General des Eaux et Forets and Directeur des Eaux et Forets du Maroc. Hence it would hardly be possible to find a more suitable author. The two volumes are full of information, not only on the general condition of the French North African forests, but also of the silviculture, management, ecology and the management needs of all the most important tree species.

The first volume deals with the varying terrain in its physical qualities, its vegetational history and the forces at work tending to destroy it or to rehabilitate it. The second volume describes the silviculture of the more important species in detail. The work is illustrated with photographs, maps, some of which are in colour and many graphs and diagrams.

This work is well worth the attention of East African readers, the first volume perhaps more to the general reader who does not know the territories described, and the second volume rather more to the technical forester, horticulturist and farmer. The general early history of the vegetation and the destructive forces of man at work on it is very similar to the earlier and also to the modern history of East Africa. It is surprising to find on the one hand what might almost be described as "political jobbery" in the giving away of forest lands, but on the other a recognition of the vital value of the forests to the country even in quite early times of French settlement. The book is of particular interest to East Africa in its descriptions of the attempts at introduction of exotics many of which are the same as our own eucalypts, pines, etc. It is worthy of note, however, that more recent information on the gums has been published in *L'Ecologie des Eucalyptus* by M. Metro.

As already mentioned it is a truly monumental work and very few territories in Africa have such a write-up of their forest vegetation, but of course technical officers of 40 years' experience in British Africa are few and far between.

It can confidently be recommended to foresters, farmers, and landowners, particularly those who are endeavouring to rehabilitate dry and semi-desert areas which have been devegetated and eroded and damaged by fire and grazing. It is a readable description of the forces at work on the land and its vegetation in Africa even to those with a comparatively small knowledge of French.

A.L.G.

COFFEE BERRY DISEASE—A SURVEY OF INVESTIGATIONS CARRIED OUT UP TO 1950

By R. W. Rayner, Plant Pathologist, Coffee Services, Department of Agriculture, Kenya

(*Received for publication on 20th September, 1951*)

Introduction

This survey is the result of a request by the Coffee Research Committee that a summary of the past work on Coffee Berry Disease should be prepared in order that its members might be able to form a clear picture of the position, and assess the advisability of pressing for further investigations to be undertaken. The amount of work which has been done on this disease in one way or another has been very considerable, but much of this has only been described in rather general terms and in a number of publications, some of which are rather inaccessible. In addition much data is only to be found in the old files of the Department of Agriculture. For some time, the writer has had the intention to summarize this work for his own benefit, and has therefore taken the opportunity of making a detailed survey of all the past investigations of which he can find any record, believing that if this is not done, much valuable information on the disease might well be lost. The story of the investigations should make instructive reading to anyone interested in agricultural research in Kenya, but those who may not be interested in the technical details of the experimental work may prefer to read the historical sketch, the summary and the conclusions only.

Coffee Berry Disease is without doubt the most serious fungus disease of coffee in Kenya, having caused the virtual abandonment of coffee-growing in many otherwise quite promising areas. Its onslaught was very sudden and spelt ruin to a considerable number of West Rift planters. Prosperous estates became a liability in a single year.

The disease attacks the green berries at any stage in their development causing a dark brown rot, which usually penetrates into the interior and destroys the beans. Eventually the whole berry dries out and takes on the appearance of *buni*. The first lesion may occur on the lateral surface of the berry causing a rapidly enlarging, roughly circular, slightly sunken, dark brown spot, or there may be a number of lesions which rapidly coalesce to form irregular sunken areas. Frequently the base of the berry and the top of the fruit stalk is first involved. The surface of the lesions develop minute slightly projecting punctuations, which may be slightly darker or slightly lighter than the surrounding tissues. These are the fruit bodies (acervuli) of the fungus and under damp conditions they may develop masses of pinkish spores. Abscission of the fruit may occur either at the top or bottom of the fruit stalk. The development of the lesions may be halted at any stage by the onset of dry conditions and thus the berry wall may at times be the only part affected. In this case the lesion often takes on an ashen-grey appearance except at the periphery where it remains dark brown. The grey area is thickly dotted with blackish acervuli and the presence of some berries with lesions of this type, a condition which has been termed "Scab" by McDonald, is considered by the writer to be an unmistakeable sign of the presence of the disease. The occurrence of sunken dark brown, more or less rounded lesions on the side of the green berries is also a reliable sign of the disease. When these symptoms are not present, there may be some difficulty in distinguishing the disease from overbearing, though the symptoms as seen in the field are usually quite distinct. Drying-out of the berries due to overbearing is always associated with die-back and the berries affected first are those on the terminal parts of the branches on the remainder of which there is always a heavy crop. Coffee Berry Disease does not cause die-back though it is not impossible for berries on a die-back branch also to be affected by the disease. Berries are affected anywhere on the branch and the crop may be quite light.

Other conditions which may be mistaken for Coffee Berry Disease are "Warty Disease" caused by a form of *Botryis cinerea* Link, Berry Moth or Butterfly, and Brown Blight. Warty Disease is distinguished by the light coloured wart-like areas scattered over the dark brown, dried-out berry, which is covered with down or mould-like fungal growth. Berry Moth or Butterfly attack is distinguished by the presence of a grub in the berry, or the hole by which the latter has made its exit. Brown Blight is closely allied to Coffee Berry Disease, and has similar symptoms but only ripening cherry is attacked.

In culture, especially on prune agar, the fungus causing the disease is easily distinguished from other forms of *Colletotrichum* by the greyish-black abundant aerial hyphae, which bear the spores directly on their branches and not on acervuli, pionnotes or other fruit bodies, as in other forms of *Colletotrichum coffeanum*. The spores are large (6-33 × 4-8 *u*) vary much in shape and size from oval, through elliptic, to somewhat irregularly clavate and have granular contents. This variability in spore shape is typical of the Coffee Berry Disease fungus and this character alone is sufficient to distinguish it from other forms of *Colletotrichum coffeanum*. The chlamydospores are formed in short chains and are very convoluted and coloured dark brown.

An Historical Sketch

The first definite report of Coffee Berry Disease on the files of the Department of Agriculture appears on the 15th October, 1922. The Senior Coffee Officer of that time, Mr. A. le Poer Trench, was on a tour of the west of the Rift coffee estates and sent the Senior Mycologist, Mr. J. McDonald, specimens of a disease which had just appeared on Mr. Hemsted's estate at Soy and, later, specimens were also sent from Mt. Elgon Estates, Turbo Valley. He reported that the disease was causing considerable damage and that it was "very serious" on the Nandi border. It seems to have made its appearance very suddenly, although there is a possibility that it had been previously confused with ordinary over-bearing die-back. Mr. Glanville, of Elandwold Estate, Hoey's Bridge, however, believed that it first appeared there in 1921 and that the specimens which he had then submitted to the Department of Agriculture were incorrectly diagnosed as damage by thrips. There is no suggestion on the files of Mr. Dowson, who was the previous Mycologist and who had recently left the Colony, of any similar disease, in fact, the first record of a form of *Glæosporium coffeanum* (Coffee Berry Disease is caused by another form of the same fungus) was made only just previously in 1920. It was apparently causing the disease which we now know as Brown Blight. McDonald refers to Brown Blight in his "Fungoid Diseases of Kenya Colony", written in June 1921, and it was then apparently of relatively common occurrence.

The isolation in the laboratory of the fungus causing Coffee Berry Disease (which will be referred to for the rest of this report as C.B.D.), was rapidly attained, and McDonald replied to Mr. Trench on the 21st October, 1922, that he suspected the disease to be due to *Glœosporium coffeanum* (=*Colletotrichum coffeanum* Noack) which under local conditions had become an active parasite. This diagnosis is essentially that which holds to the present day.

McDonald toured the area from which the disease had been reported the following month, and formed the conclusion that neglect was almost invariably associated with bad attacks of disease. It is now known that extremely well-managed estates can get very bad attacks, but the high humidities engendered by unpruned and unweeded coffee undoubtedly predispose the trees to attack. Many estates at that time had been badly neglected, and no doubt this explains McDonald's finding.

A warning circular was issued the following month, in which the symptoms of the disease were described and suggestions made as to the measures which it was considered should control the disease, the emphasis being that neglect of the trees was at the root of the trouble. The control measures were:—

1. Proper control of weed growth.
2. Removal of all dead branches, which were to be burnt.
3. The employment of correct pruning practices to promote vigorous growth.
4. Spraying with ½ per cent Carbide-Bordeaux.

Naturally, none of these had actually been tried out, but there seemed no reason at the time why spraying—which is a standard "cure" for most fungal diseases of above-ground parts—should not be successful, and it took a very considerable amount of adverse reports from planters and a number of experiments, before this faith was shaken. The proper control of weed growth and the employment of correct pruning practices were connected with the generally-accepted opinion in those days that it was only weakly plants which were affected by disease. This, although having some truth as a generalization, is now known to have many outstanding exceptions, the present disease apparently being a case in point. The removal and burning of infected plant material was a sound precautionary measure until its effectiveness or otherwise had been shown. The Government made arrangements to loan out spraying machinery, and organized the supply of spray materials.

McDonald soon found that a special form of *Colletotrichum coffeanum* was constantly associated with the disease, this form being relatively easily distinguished from those associated with Brown Blight of berries and leaves, die-back, etc.

There seems to have been a lull in the attack of the disease during the next few years, but McDonald continued investigations and although he was not very successful with inoculation experiments at the Scott Laboratories, he produced the disease by inoculation of wounded green berries with artificially-grown fungus cultures in an experiment in the Turbo Valley (Mt. Elgon Estates) in July, 1924. It was thus proved to be undoubtedly primarily due to fungal attack. Confirmation of the identity of the fungus was also obtained, i.e. that it was a strain of *Colletotrichum coffeanum* Noack, about the same time. Although numerous attempts were made, closely related strains of the same fungus only once produced the disease when inoculated into green cherries, and this may have been due to a chance external infection.

On the 25th October, 1924, the first questionnaire was issued to seven coffee planters, from whose answers it was concluded that spraying did hold the disease in check.

The idea that a vigorous plant would be resistant to the disease early led to manurial trials. The first one carried out tested potash alone, potash plus phosphates, and potash plus *boma* manure against no manure, and was laid down on Mr. Johnson's estate at Turbo. Unfortunately, it was attacked by leaf-eating caterpillars and no results were obtained. About the same time, selection of trees for their resistance and their propagation by seed was advised and apparently carried out on some estates. All experiments at this time had to be in co-operation with farmers, as the area concerned was at a considerable distance from headquarters, and staff to look after any experiments was lacking.

The vagaries of the distribution of attack on both individual estates and from estate to estate in the same area, gave rise to the suspicion that perhaps some soil factor was responsible, and examinations of soil samples were started, apparently without much success.

Early in 1929, a spray trial to test Ky-Bordeaux was set up on Jamji Estate, Kericho, in co-operation with Mr. Lydford. Towards the end of the same year Mr. Trench was emphasizing the serious nature of the disease. It was becoming increasingly obvious that spraying was not controlling it sufficiently and Trench pressed for investigational work to be carried out. The result was that a number of co-operative experiments on various estates in the Sotik area were set up and Mr. Stone, Plantation Inspector, was detailed to look after them.

Mr. Gethin-Jones, then newly appointed as Soil Chemist, toured the main C.B.D. areas in July, 1931, and made a survey of the soils. Laboratory analyses were carried out on representative profiles, and especially on adjacent areas with and without a reputation for getting the disease. He concluded that soils were not a major factor influencing the attack of C.B.D. and considered that microclimatic factors were possibly more important in determining its erratic behaviour. At a later date he added differences in past history, cropping, age, etc., to this. He emphasized that large-scale differences in intensity of attack were correlated with altitude change.

Experiments on various types of sprays, injection and spraying with minor nutrients, ringing and stripping of crop from certain flowerings followed. In March, 1933, McDonald admitted that these experiments had led to no new discoveries. Copper sprays varied much in effect; sulphur-containing sprays had no effect at all and results with oil sprays were neither "reliable" nor encouraging. Manures containing phosphorus and potassium and dressings of lime had not helped, but the resistance of Blue Mountain coffee and of certain bronze tip selections was definitely proved.

A questionnaire was circulated to 210 planters late in 1933, but only 31 replies were received. This apathy was surprising, considering the alarm which had been expressed about the disease.

As the co-operative experiments did not seem to be giving any answers, and as the disease was now causing considerable losses, a small experimental station was opened on Sotik Estate, Sotik, the coffee being leased from the owner by Government. Mr. Wilkinson, then Entomologist, and Mr. Cottington, then Plantation Inspector, were posted to the station, the former looking after the experiments and the latter carrying out work on developing methods of vegetative propagation, and on the selection of resistant varieties. During the period it functioned, a considerable range of investigations were carried out on many different types

of sprays, on manuring, pruning, selective stripping of crop, competition for soil nitrogen, and so on. The results of all these were either negative or of insufficient effect to be of any use. Only the discovery of resistant varieties, of which Blue Mountain was the best, seemed to hold out any hope.

A third questionnaire was circulated to planters early in 1936 and the results published a year later. One hundred and seventy-six replies were received and it was, therefore, a fairly representative sample of planters' observations. All West Rift coffee planters (about 500) were circulated, and some 55 per cent of those replying reported C.B.D. present; only 12.5 per cent reported losses averaging over 25 per cent of the crop. The general relation with altitude was clearly demonstrated and the association with cold wet conditions was confirmed. Prevalence in hollows, valleys and low situations was frequently reported.

The Sotik station was closed down in March, 1937, except for the maintenance of some of the coffee varieties under test. This was because it was found to be too isolated and therefore difficult to run; also coffee was no longer grown to any extent in that area. Investigations were continued at the recently established experimental station on Kepchomo Estate, Nandi. Owing to the war, a European officer could not be maintained at the station, but the experiments were continued by Mr. G. Mordaunt, a planter on a neighbouring estate. However, little of further interest was discovered and the station was finally abandoned in May, 1944, trials of certain coffee varieties being continued on Savani Estate, Nandi. Kepchomo, it had been found, was not a good choice for C.B.D. experiments, as it was so high that loss from C.B.D. was not the limiting factor for yield, but rather the extremely shy bearing habit of the trees under these conditions.

In 1939, a small outbreak of the disease was discovered at Nyeri and was investigated by the present writer. It was then found that the fungus could exist in a "latent" condition in leaf tissues and, in consequence, some work was carried out in Nandi in February, 1941, in the hope of solving the mystery of what happened to the fungus during the "off" season. It was concluded that the only theory which seemed to agree with the ascertained facts was that the actively parasitic form of the fungus arose from the very numerous *Colletotrichum coffeanum* infections which occur all over the coffee bush, especially in the bark tissues; a change of form being undergone on invasion of green coffee cherries. It would appear that it is only under certain physiological conditions of the host fruit that an actively parasitic form of this fungus arises. This theory has not been tested further as yet, but it is hoped that the opportunity will arise during the present investigations of the relation of latent infections of *Colletotrichum coffeanum* in the leaf to leaf fall and tonic copper spraying.

The disease was reported from the Kivu district of the Belgian Congo in 1938. Similar difficulties have been experienced in controlling it and the main line of defence is now the selection of resistant trees.

An investigation of the performance of the Blue Mountain variety of coffee by the present writer in 1943, showed that it was only immune in areas of border-line altitude for C.B.D. attack, i.e. that the ceiling at which it began to get the disease was some 200 ft. higher than that for ordinary French Mission types; the reverse is, incidentally, true for the Harar variety. At any given altitude, however, Blue Mountain is less attacked than any other variety.

An experiment in 1943 on complete stumping and firing of an infected plot of Harar coffee at the Kitale Experiment Station showed that the very first crop following this extreme measure was badly infected with C.B.D. This demonstrates the futility of attempts to control the disease by ordinary methods of "orchard" sanitation.

The Investigations

In this section, the investigations which have been carried out will be listed, described and their results given. They will be grouped according to their nature, e.g. mycological; environmental (including climate, soil and the plant itself); manurial; fungicidal spraying; selection and propagation of resistant varieties.

1. *Mycological Investigations*

No difficulty was encountered in isolating the causal fungus from infected tissues and this procedure soon became standard for settling doubtful cases of attack. In the writer's experience, it is not always easy to isolate the fungus from old material, as secondary organisms tend to swamp the C.B.D. fungus; and when it is of importance to be sure as to whether C.B.D. is to be implicated or not, isolations from fresh material in the field should be made.

McDonald found that only a certain, rather peculiar form of *Colletotrichum coffeanum* Noack seemed implicated. Early attempts at wound inoculation of green berries (growing on the trees?) at Kabete were made, but only 5 per cent produced symptoms of the disease. The fungus was, however, reisolated from these.

Inoculations of flowers were carried out on Mr. L. A. Johnston's estate in the Turbo valley, but were unsuccessful. Inoculations by needle punctures of green berries on Mr. Johnston's and on Mt. Elgon Estates [4]*, both in the Turbo valley, led to successful production of the disease in a high percentage of cases. A Phoma sp. not infrequently isolated from diseased berries, and the Brown Blight form of *Colletotrichum coffeanum* did not produce the disease (except for one doubtful case with the latter). Further inoculation experiments confirmed these results. Inoculation of leaves and twigs did not produce any symptoms. A study of *Colletotrichum coffeanum* forms isolated from other coffee material showed that although these exhibited great variation in form, that typical of C.B.D. was never found. Although they tend to change their form in culture, no form similar to that of C.B.D. was ever observed to be produced.

The C.B.D. fungus was submitted to authorities on the classification of the genus *Colletotrichum*, and it was considered that it should be regarded as a form of *Colletotrichum coffeanum* Noack, whose perfect stage is known as *Glomerella cingulata* (Stonem) Spauld et V. Schr. The perfect stage, in the case of the C.B.D. form has, however, never been observed.

It appears that some work was carried out by McDonald in 1937 on the production of the disease by inoculating detached branches in the laboratory, and apparently success was obtained without wounding the berries merely by spraying suspensions of spores on to fruiting branches of Harar coffee. At the same time, symptoms of the disease were produced by inoculating wounded cherries on detached branches of Mysore coffee. No detailed account of these experiments is available.

No record can be found of attempts to produce the disease without wounding in the field, and so there have been no studies of the conditions necessary for infection under natural conditions.

McDonald [4] tried the effect of growing the C.B.D. fungus on culture media prepared from coffee berries from adjacent areas with and without the disease (and, incidentally, with and without liming), and found that it grew best on the former, indicating apparently, a chemical difference in the coffee berries from the two areas.

McDonald [26] made a study of viability of the spores under various temperature regimes and showed that it was killed after three days at 104°F. Diseased berries should, therefore, be free of infection if made into compost where this temperature is maintained. Pure coffee pulp does not heat up as much as this, and extra material such as grass must be added (11, p. 163). In view of our present knowledge of the disease, it is doubtful whether such precautions to destroy infection would really be of much use.

McDonald also carried out a number of experiments on the toxicity to C.B.D. spores of rain which had been in contact with copper-sprayed berries, but got very erratic results ([28] p. 124 and [29] p. 146). A study of the toxicity of copper and oil spray films showed the former to completely inhibit germination of spores, but the oil films did not seem to have any effect ([28] p. 124).

In 1940, Rayner [18] made some investigations on the nature of *Colletotrichum coffeanum* infections in coffee in relation to the small outbreak of C.B.D. at Nyeri. He found that fungi of this species, and also species of the genera *Phoma* and *Phomopsis*, were abundantly present in all apparently healthy tissues of coffee examined. In a few cases, the form of *Colletotrichum coffeanum* associated with C.B.D. was found in the leaf tissues. Further observations in relation to "weak spots" confirmed the ubiquitous nature of what have been termed "latent infections". In 1949 some experiments showed that these infections are very superficial [35].

The results of the investigations on the "latent infections" caused by *Colletotrichum coffeanum* were communicated verbally to F. L. Hendrikx, who was working on the disease in the Congo, and who, in his report for 1940–41 [16], confirmed the results in respect of Congo coffee.

Since the C.B.D. fungus had been found in other tissues than those of the berry, it

* Numbers in brackets refer to those in the list of references appended.

seemed that some explanation of what happens to the disease during the months when it is not present in the field might be obtained, and in February, 1941, a careful search for it in various parts of the plant, living and dead, was made on Savani Estate, Nandi, cultures being made on the spot. In no case could it be isolated, though very soon afterwards the disease made its appearance in the field. It was found, however, that each part of the plant tends to have its own form of *Colletotrichum coffeanum* and, in fact, a graduated morphologic series can be made commencing with those found in the dead tissues of the bark and terminating with the actively parasitic C.B.D. form [18]. It is thought that the chemical constitution of the green berry in C.B.D. areas is possibly such that an ordinarily very mildly parasitic fungus, capable only of invading the superficial tissues and behaving as a "latent infection" and not developing further until the tissues die, becomes actively parasitic, and that the consequent change in activity is reflected in a change of form. McDonald's experiments reported above are hardly sufficient to disprove this theory and in fact, he does report one case of Brown Blight fungus apparently producing the symptoms of C.B.D. In any case, natural infection was not obtained, as wounding was always resorted to.

Some observations made by Mordaunt on the incidence of berry fall in the Nandi region are of interest. He observes that in 1940, berry fall, which usually precedes C.B.D. had continued throughout the season and had been particularly bad, causing considerable loss of crop. Leaf disease was also in evidence though C.B.D. itself was slight. Mordaunt believes that in some years there is bad C.B.D., little leaf rust or berry fall, and in other years the position is reversed. On a recent visit to Savani Estate, the author found that the same phenomenon had just been observed. 1949 had been a bad C.B.D. year, whereas 1950 had seen very considerable loss due to berry fall. Mordaunt and others have considered that there might be some connexion between berry fall and C.B.D. and have suggested that they might be caused by the same fungus. Some attempts to isolate the C.B.D. fungus from the pedicels and bases of fallen cherries by the author in July, 1940, were negative, but only material sent through the post was used. There seems no doubt that in the Nandi area, at least, berry fall, which may at times affect almost fully developed berries, is a serious cause of loss of crop and low yields.

Green made some observations on berry fall in the lower Songhor and Muhoroni areas and believed it was due to competition between crops from October and January flowerings, the latter falling off in the pin-head stage. In the author's opinion, this is similar to a phenomenon observed by him in the East Rift, especially in the Mitubiri-Makuyu areas, and which he has shown to be due to a deficient carbohydrate supply to the young fruit [34]. He does not consider it to be quite the same as that observed on Savani, though it may still be fundamentally due to the same cause, perhaps, in the latter case, brought about by competition for carbohydrates by vigorous vegetative growth.

2. *Environmental Factors*

Observations on the effect of environment, although copious, were rarely systematically pursued and most of the conclusions drawn were really of the nature of informed opinions rather than of scientifically determined facts. In view of this, in most cases it will not be possible to list observations and merely the conclusions will be given.

Climate.—That there is a general tendency for C.B.D. to increase with altitude may now be taken as a definite fact, though the first record of this having been observed seems to be as late as Gethin-Jones' soil survey in 1931 (apparently unpublished). There are a number of climatic factors associated with increasing altitude; lower average temperatures, increasing rainfall and humidity being the principal. The low rate of attack on the estates on Mt. Elgon compared to that on the adjacent and lower Kitale estates forms an interesting exception to the altitude rule.

In the analysis of the replies to the 1936 questionnaire [12], McDonald produces definite evidence for this trend with altitude from the planters' reports of disease intensity. 5,500 ft. is shown to be the approximate altitude below which the disease does not occur in the West Rift areas. He also deduces a slight trend for increasing disease with increasing rainfall. It used to be considered that high rainfall was invariably associated with C.B.D. together with a "West Rift" distribution, but the occurrence of the disease at Nyeri in the East Rift area with a rainfall of only about 36 in., shows that this is not invariably so.* However, in this

* The disease has this year (1951) also appeared in the main East Rift area at altitudes from 5,800 ft. to 6,400 ft.

case, high humidities associated with misty conditions due to the proximity of high land mass (the Aberdares) may be the key. On the other hand, there is some evidence that low temperatures are important and the probability is that the combination of both these factors is required. In the analysis of the 1936 questionnaire, the association of the disease with hollows, low-lying areas, valleys, etc., definitely emerges, but McDonald considered that it was the high humidities associated with such positions which were more likely to be the cause of the increased disease, rather than the associated low temperatures. Western aspects were usually reported as the worst affected.

There appears to be a fairly general agreement that wet conditions are associated with the disease. Thus, the majority of planters replying to the 1933 questionnaire [7] were agreed on this point, and there was general agreement that the peak of the attack occurs in cloudy weather with no sun. The same points emerged in the 1936 questionnaire, where an analysis of replies as to monthly intensity indicated a gradual rise through the year to July and August and then a similar gradual decrease, the minimum being in December and January. Hendrikx [17] observes that renewed attack always follows a shower of rain.

In spite of the general relation between altitude and C.B.D. attack, very marked variations can occur from estate to estate, and even from block to block or within blocks on one estate. Gethin-Jones, in his soil survey, considered that much of this variation might be due to the collection of cold air in hollows and along the bottoms of plantations. The preference of C.B.D. for hollows has been frequently observed. He also observed that the demarcation of blocks frequently coincided with changes in C.B.D. distribution and concluded that past history, treatment and age of the coffee played a large part. I am informed by the Meteorological Department that minor topographical features can quite easily produce considerable variations in temperature regimes.

Temperature readings were initiated by Stone in the Sotik area in 1932, and detailed meteorological observations were taken on the Sotik Experimental Station by Mr. Wilkinson. In 1934, Mr. Wilkinson took very detailed meteorological observations of hourly variations in temperature (during daylight only), humidity and dew point, together with various measurements such as rainfall, wind-speed, Piché evaporimeter readings, hours of sunshine, etc. These observations were never published, but are in the archives of the Coffee Research Station. He also took observations on the variation in C.B.D. attack during this period and attempted to relate his climatic observations to this variation. His analyses of the data were never completed, but as far as he went, he was unable to come to any definite conclusions.

Although it seems to have been admitted that temperature might be an important factor in accounting for the vagaries of C.B.D. distribution, no detailed study has ever apparently been published, though considerable data were accumulated in the Nandi region during the period the Kephomo station was in operation. In August, 1937, wet and dry, maximum and minimum thermometers were installed in grass screens and later partly in standard screens at Kepchomo, O'Lomotet (Whittall) and Kaamasai (Mordaunt) Estates, two observation points 50 yds. apart being used. Only small differences were observed to occur between the pairs of observation points, and between standard and grass screen readings.

In May, 1938, standard screens placed at the normal height (i.e. just above single stem coffee) were set up as follows:—

Kaamasai Estate.—No. 1. On ridge with no C.B.D. In August shifted to O'Lomotet Estate where no C.B.D. No. 2. In hollow, where C.B.D. is always rife.

Kepchomo Estate.—C.B.D. always bad. Screens set up in coffee under shade and about 100 yds. away out of coffee in open.

Savani Estate.—No. 1. Block 3 with no C.B.D. No. 2. Block 22 a C.B.D. area.

The readings were taken by an African recorder at 9 a.m. and 7 p.m., but were found to be unreliable, the maximum and minimum thermometers not being reset. The indication at Savani was that the C.B.D. area was slightly cooler in the early morning. Thermohygrographs were installed at Savani and recording was carried on until the end of 1940. Thermohygrograph records were also kept at Kepchomo until it was closed down. No analysis of the results ever seems to have been made. Ordinary thermometer readings were continued at Kaamasai, but the only report on the findings is the following, which is an extract from a letter by Mordaunt in April, 1940:—

". . . C.B.D. (is) first evident here (Kaamasai) in the areas where the nights are

colder and the variation in the 24 hours greater, that is in pinch-tip areas. An example is one tree (copper tip type) which has quite a bit of C.B.D. near the lower thermometer here, whose readings show a minimum of 45-55° over the last two months and a daily variation of 20° to as much as 48°, average 35°. More temperate places (minimum 60° average and difference 20° average) show no C.B.D. or pinch-tip."

Some records for humidity at 9 a.m. and 3 p.m. for 1939 and 1940 for the Scott Laboratories, Kepchomo and Savani Estates (only for 1940), are to be found on the files. At 9 a.m., the Scott Laboratories had consistently higher humidities than Kepchomo or Savani and consistently lower humidities at 3 p.m. except in 1940, in January, when the humidity was much lower at Kepchomo than at the Scott Laboratories. This is surprising and suggests there may have been an error. Savani was generally intermediate.

Shade has been reported as having a very varied influence on the disease. Leguminous shade has been considered to have an adverse effect. Potter, of Mt. Elgon Estates, in 1929 reported that in blocks of coffee with a large diurnal range, shade was essential, unshaded coffee being badly attacked. A number of planters replying to the 1933 and 1936 questionnaires [7] [12] thought heavy shade induced bad attacks, others thought it had no effect; others still, thought it reduced the disease. Recently, the writer observed an area at Mweiga where C.B.D. had suddenly put in an appearance in a patch of coffee in a valley where shade had recently been removed. The disease was largely confined to the unshaded area, which apparently differed in no other way from the adjacent shaded coffee. He believes the increase in diurnal temperature range was probably responsible. Under heavy shade on the other hand, the heightened humidity may be the cause of increased attack.

Areas where "red thorn" (*Acacia sp.*) are native, have been considered to be associated with C.B.D. attack. McDonald, in his analysis of the replies to the 1936 questionnaire, could not find any relation to the type of natural vegetation of the area, including that of red thorn.

Hail damage has often been reported initiating a heavy attack of C.B.D., e.g. at the Sotik Experimental Station in 1936 [10]. Several planters in their replies to the 1936 questionnaire said that they thought that an attack of C.B.D. often followed hail damage.

In July, 1940, Mordaunt (in correspondence) observed that in his experience C.B.D. brought on by a hail storm, often started on the side of the fruit not actually damaged by the hail stones. This observation suggests that it may be the low temperatures experienced during a hail storm, rather than the actual mechanical damage, which brings on an attack of C.B.D.

From the data available, it would seem to the writer that whilst both climate and microclimate do play an important role in determining the attack of the disease, these are often not the key factors, which may well lie in the physiology of the bush. True, this physiology may be in part a reflection of the climate, but it is an integrated historical one. In other words, the climate or microclimate over a period of time may affect the physiology of the bush and this in turn determine whether the disease makes its appearance or not. This may account for the difficulty which Wilkinson encountered in trying to carry out his correlations in the field. Large-scale environmental control chambers are probably the only means by which the problem could be satisfactorily investigated, and the interaction of climate with the physiological condition of the bush would have to be taken into account.

Soil.—It was long thought that the only possible cause for the extreme local variations in C.B.D. attack must lie in the soil. McDonald's experiments with the growth of the fungus on media from attacked and unattacked adjacent areas seemed to suggest this possibility, and Beckley (in correspondence) considered that symptoms of lack of potash were common in the C.B.D. areas.

Some early work was carried out by Gracie in 1929 ([26], p. 224) but he could come to no conclusion as to possible correlations with soil factors, and was unable to pursue the matter further due to pressure of work of more general import. Gethin-Jones, soon after his appointment in 1931, made a survey of the area, and carried out numerous soil analyses and a few plant analyses in addition. He found that the soils of C.B.D. areas were very varied, many occurring frequently both within and without attacked districts. He could find no correlation with change of soil type from one part of an estate to another. He made a number of careful studies of small areas on estates with a reputation for getting C.B.D. more seriously than adjacent areas, and made comparative

analyses of the soils from such areas, but could find nothing in the results constantly associated with C.B.D. attack. In the analysis SiO_2, CaO, MgO, and $FeAl_2O_3$, in a 2N ammonium acetate extract were determined together with pH. Some additional analyses of topsoils only were made, in which moisture content, loss on ignition, total nitrogen and "available" K_2O, Na_2O, and P_2O_5 (i.e. extracted by 0.5N nitric acid) were determined. The results of these analyses are available in the archives of the Coffee Research Station. The plant analyses were similarly unhelpful, but the number was rather small, often not strictly comparable, and the factors determined were rather few. They included moisture content, ash, SiO_2, R_2O_3, MnO, CaO, MgO, K_2O and Na_2O, and were thus aimed at detecting shortages of the main mineral nutrients.

In 1934, Beckley pointed out (in correspondence) that the soils in the C.B.D. areas showed all the signs of podsolization, with consequent leaching of heavy metals from the soil, and that the zone of accumulation would be beyond the range of the coffee root system. He considered that an investigation of minor element nutrients should be carried out and that an application to the Colonial Development Fund to finance the purchase of a spectrograph should be made. This was done and an instrument obtained. The use of this proved rather complicated and it was obvious that reliable results would only be obtained by a full-time worker. In consequence, it was transferred to the Amani Research Station and spectrographic work on C.B.D. was not carried out. The effect of various minor nutrient sprays was, however, tried and will be reported under the section on manurial experiments.

Poor drainage and the presence of old *boma* sites have been held to cause local variations in C.B.D. attack ([11], p. 154). Poor drainage was mentioned by a few planters as being associated with increased C.B.D. attack in the 1936 questionnaire.

The Composition and State of the Plant.—The few analyses of the plant carried out have already been mentioned. Various observations as to the physiological state of the plant, however, have been made and attempts were made to influence this by various treatments. An account of the latter will be given in the section on "physiological" experiments.

It was originally considered that the disease was one which only affected neglected, unpruned and unweeded coffee (e.g. [1]). More recently, opinion swung round to the opposite extreme and it was considered that it was the most vigorous plants which were most affected ([11] p. 155). In this connexion, it is of interest that the very vigorous variety Harar is very badly attacked. A method of pruning, i.e. Parrot Perching, was one of the first panaceas suggested. However, by the time the 1933 questionnaire was produced, no planter considered that there was any effect of pruning methods on C.B.D. attack. In the 1936 questionnaire, a few thought multiple stem was less affected, one that it was more affected than single stem and a number mentioned dense foliage as being conducive to it.

In 1932, McDonald was advising pruning so as to obtain crop on vigorous wood only, and on the Sotik station an experiment was put down to test this idea. There was apparently no replication. Vigorous wood and stout primaries were obtained by cutting away, flush to the main stem, primaries which had become weak and whippy. All secondaries were removed and centering and handling was carried out three times during the year. No precise results appear to have been reported, but apparently the neglected control plot yielded no crop that year, whereas the well-pruned plot yielded 4 cwts/acre with 28 per cent C.B.D. It was concluded that pruning to obtain vigour did not control C.B.D. but counteracted its affects by producing a large crop.

In the experience of Mr. L. S. Drayton, of Merton Estate, Kitale, who had attempted to rehabilitate certain neglected weedy and couch-filled blocks of coffee on this estate, the vigorous trees produced by the rehabilitation were the worst affected by C.B.D.

Some observers, e.g. Trench and Thompson (in correspondence), thought that the stage of development of the bean had an effect on susceptibility to the disease, berries containing beans in the milky stage being more prone to attack than when the hard stage had been reached.

Several experiments were carried out on the effect of selective stripping, in view of these observations. It was also considered that reducing competition between crop at various stages might be beneficial. The first experiment of this type was carried out by Stone on Chebango Estate, Sotik, in 1932. There were three blocks of 20×20 trees. Half of each block was left as control and the three following treatments applied to the three remaining halves.

1. Only short rains flowerings of 1931 and 1932 to be left on the trees.
2. Short rains flowering 1931 and long rains flowering of 1933 to be left; the rest to be stripped.
3. Long rains flowerings of 1932 and 1933 to be left; short rains flowering of 1931 to be stripped in April 1932, and that of 1932 to be stripped as formed.

A further stripping experiment, in which one quarter, one half and three quarters of the crop on each branch of 20 trees was to be removed, was apparently set up later in the same year, and possibly on more than one estate.

No results of these experiments appear in the records and presumably no striking effects were observed.

In 1933, a stripping experiment was set up on the Sotik station. Two plots of 5×12 trees were used, only the short rains flowering crop being left on one and only the long rains crop being left on the other. A control strip down the middle of each plot was left untreated.

In both 1933 and 1934 no long rains flowerings were obtained. In 1936, the percentages of infection were as follows:—

	Per cent infected
Short rains crop	16.7
Control	19.6
Long rains crop	1.0
Control	19.7

It seems that in this year the long rains crop was definitely much less infected than the short rains crop. However, it only amounts to 68 per cent of the crop from the short rains flowering plot in spite of this lower infection. It must be remembered that this crop was on trees which had not cropped for two years and McDonald [11] suggests that the difference in infection may have been due to the rest the trees had had, rather than in a difference in susceptibility of the long and short rains crops. He believed that such a rest "permits the bushes to accumulate nutritional reserves of some kind which confer a certain degree of resistance on the ensuing crop". An effect on the level of inoculum might also be a possible explanation.

In view of the small amount of crop normally obtained from a long rains flowering, supposing a lower rate of infection was a regular phenomenon, confining cropping to this flowering would not be a practical proposition, as much less crop would be obtained, unless some way of increasing its amount could be devised.

In 1935, reduction of crop to one-quarter and one-half was tried on two plots with a control strip each. Half gave 6.6 per cent infection as against control 18.6 per cent, but only gave 60 per cent of the yield. Three-quarters of the crop removed gave 18.9 per cent infection as against control 30.3 per cent and the yield was 50 per cent of the control. There was thus some evidence that reducing the crop does reduce the incidence of C.B.D., but the loss of crop due to stripping is greater than that due to C.B.D. without stripping, so that it is not a practical means of control.

In 1936, an experiment was started to compare the effects of forcing the trees to enter a vegetative, non-cropping period, using either parrot-perching or stumping. The experiment was not carried through.

In a memorandum prepared by A. W. Thompson, of Kapchorua Estate, Nandi, in November, 1935, it is stated that, as a matter of general observation, the percentage infection of a crop from the October-November flush is much higher than from the subsequent February flush. He states that there is evidence that after a certain point, the average susceptibility of a group of coffee trees diminishes, provided no drastic alteration of the trees takes place such as stumping or very heavy pruning. Up to a certain age, in addition, susceptibility is less. Thus susceptibility, he believed, increased and then decreased with increasing age. The same was held to be true for the individual coffee cherry.

McDonald in "Coffee in Kenya" [11] states as a matter of general observation that, with rare exceptions, the first few crops on young trees escape serious infection, even when older badly infected trees are growing alongside. When the disease eventually appears, it tends to become more severe in succeeding years. If such trees are then stumped, the young suckers are less affected, becoming more so as their age increases. It is interesting that in the new isolated Kisii area, C.B.D. did not make its appearance until the end of the first cycle of multiple stem, and thus more or less repeated its history in the older coffee areas. McDonald advances the theory that "in the first years of purely vegetative growth before cropping begins, the bushes accumulate stores

of reserve materials which serve the needs of the first crops. Requirements in later years exhaust the supplies of some essential materials and predispose the berries to attack by the disease". However, no precise measurements appear to have been made as to the relative freedom from attack of young coffee and, in their absence, it is perhaps inadvisable to base too much theory on relatively subjective observations. To the writer, the most likely explanation would appear to be the reduction of potential sources of infection and careful testing of the disease rates on new suckers produced on trees dotted about at random in a block of coffee with old heads with a high rate of infection would be necessary to disprove this possibility. However, there is certainly no doubt that young growth is physiologically different from older, as witness its much higher rate of flower production per node.

According to Mr. Cottington (private communication), several planters in the Sotik area lost the entire crop in the first year that their young coffee came into bearing. Further, Mr. Guy stumped the whole of Sotik Estate around about 1936 and the first crop on the new suckers was entirely destroyed by C.B.D. There is thus no prospect of a useful control of the disease by obtaining crop on young growth only.

Examinations of starch reserves in branches, trunks and roots were carried out by Wilkinson at Sotik [7] using iodine applied to cut surfaces. He found that reserves of starch were present in trees badly attacked by C.B.D.

During the recent outbreak of C.B.D. in the Upper Kiambu area, the writer investigated the starch contents of branches bearing berries badly attacked by the disease and found them to have abundant starch reserves.

Numerous attempts to influence the C/N ratio were made, though no analyses to check whether the C/N ratio was indeed affected, were carried out. These experiments will be described in the section on manurial treatments. No effects on incidence of infection of C.B.D. were observed.

Ring barking was tried by Stone in 1931, but no results appear on record. Experiments on root damage, on subsoiling and on time of pruning were laid down in 1936 at Sotik, but no results were obtained owing to the virtual closing down of the station in that year. A drainage experiment was laid down in 1934, but no record of any results can be found.

3. *Manurial Experiments*

The first manurial experiment was set up on Mr. Johnson's farm at Turbo in 1926. It consisted of two blocks of four treatments each randomized (?) within the blocks. The plots were 10 × 32 trees, and the treatments were:—

1. No treatment.
2. Muriate of potash, ¼ lb. per tree.
3. The last plus steamed bone meal, ½ lb. per tree.
4. Muriate of potash as in 2 plus 40 lb. of *boma* manure per tree in a 2 ft. trench between the trees.

Leaf-eating caterpillars stripped the trees of leaf early in 1927 and apparently the experiment was abandoned without any results being obtained.

Although various manurial experiments are alluded to vaguely in the literature and in the correspondence files up to 1929, no details are given and they were possibly purely planters' experiments.

Towards the end of February, 1930, McDonald visited the Sotik area and set up a number of manurial experiments with the help of H. Stone, Plantation Inspector on Maramura Estate (Commander Coke), Kericho; Mutarakwa Estate (R. Mayers), Monieri Estate (T. Haslehurst), Sotik; and Itare, Ltd. (G. Norman), Kericho.

The layout was a systematic one and consisted of two sets of four plots each making eight plots in all; the plots were five lines of coffee broad by ten bushes deep, i.e. 50 trees, a single guard row separated the plots. The layout was as in Table 1.

TABLE 1

Control	K	Control	K & P	Control	K	Control	K & P

K = 300 lb. sulphate of potash per acre.

P = 600 lb. superphosphate per acre,

A liming experiment using local ground limestone was also suggested, to be employed at the planter's discretion. The plots were the same size as above and the layout was as in Table 2.

TABLE 2

Control	10 cwt. per acre	Control	1 ton per acre	Control	2 tons per acre	Control	3 tons per acre

In 1932, potash, ½ lb per tree, and phosphate, 1 lb. per tree, were applied to the highest limed plots on Maramura and Mutarakwa Estates.

No spray was to be applied, but the normal farm practice of organic manuring was to be carried out. On Jamji Estate, (S. T. Lydford), Kericho, apparently a slightly different layout was used, this experiment being entirely the planter's concern. It was probably designed as in Table 3.

TABLE 3

N P	C	Sterameal K P	C	Goat Manure
C		C		C
N K	C	Sterameal	C	Beans
C		C		C
P K	C	Lime	C	Beans P K
C		C		C
N P K	C	N P lime K	C	Goat Manure P

N = Sulphate of Ammonia.
P = Single or Double Superphosphate.
K = Sulphate of Potash.

Beckley suggested the complete fertilizer, Sterameal, was too costly for practical application and also that the scheme should be duplicated. Mr. Mordaunt of Kaamasai Estate, Songhor, also volunteered to do experiments on these lines and apparently set one up the following year.

Eye observations only were to be carried out on the plots for estimation of crop and intensity of C.B.D., but Stone obtained permission to make counts of cherry and C.B.D. infected berries produced. In December, 1930, McDonald refers (in a letter) to fertilizer experiments he had seen at Taita and Savani Estates in Nandi, which he thought showed a reduction in C.B.D. where fertilizer dressings had been given. Apparently no effects could be detected in August, 1931, ([27] p. 119). Sulphate of potash and superphosphate were applied to one of the limed plots on each of the two farms where liming experiments were in progress.

Following on Mr. Gethin-Jones visit to the area in 1931, a number of additional experiments were initiated as follows:—

1. *Nutrient spray trials.*—Spraying to be carried out at 20-30 day intervals until further notice, in the early part of the day and to be repeated if rain followed. Individual primaries were treated using a "Flit" pump at Kama Kosa Estate using decimolar strengths. At Mutarakwa whole heads were treated with one-third this strength at about 1½ pints per tree. The chemicals used were apparently:—

1. Iron sulphate.
2. Manganese sulphate. ($Mn\ So_4$).
3. Sodium phosphate (Na_2HPO_4).
4. Potassium chloride.
5. Iodine.
6. Sodium nitrate.
7. Sodium silicate.
8. Magnesium chloride.

Gethin-Jones initiated these experiments on 15th July, 1931, himself, and apparently performed further similar tests on Kivoga Estate (J. K. Matheson) and Craigmore, both at Sotik. Apparently single branches were sprayed in these last and the progress of the disease followed by counting.

2. *Tree inoculations.*—A slit was made in the bark of the trunk and fluid containing the chemical squirted in. This was repeated on the other side of the tree. It was found that the solution was not absorbed to any extent and later was applied through holes bored in the tree trunk, downwardly directed at an angle to the horizontal and about ¼ in. in diameter. The treatments which were to be carried out were:—

(*a*) Six alternate trees inoculated with 1½ per cent ferrous sulphate.

(*b*) Six alternate trees in an adjacent row with ½ per cent sodium chloride.

(*c*) Six alternate trees in a further adjacent row inoculated with 1 per cent magnesium sulphate.

Apparently the treatments were to be repeated at monthly intervals, presumably on additional trees. Inoculations with ferrous sulphate and sodium chloride were apparently also carried out at Kivoga Estate, Sotik, by J. K. Matheson; inoculation with rain water formed a control.

3. *Mineral liquid manuring.*—Fertilizer (not stated) was to be dissolved in water and poured into six holes 2 ft. deep at base of each tree. Also six additional trees at each estate were to be treated with ferrous sulphate solution, at a rate of 200 lb. per acre, the amount per tree to take into account spacing and to be dissolved in 8 gallons of water. Half the solution was to go into the holes, the rest to be distributed under the spread of the trees. Six additional trees were to be treated similarly, but with $MgSO_4$ at 200 lb. per acre.

Observations were to be by eye, but Stone worked out a system of counting C.B.D. and non-C.B.D. berries, which was apparently accepted.

Ferrous sulphate sprays were found to damage the leaf tissues; inoculations with ferrous sulphate in the experiments carried out by Gethin-Jones at Kivoga were reported to have been followed by an interruption in the progress of the disease.

In November, 1931, 50 tree plots at Maramura and Mutarakwa Estates were treated with ferrous sulphate at 100 lb. per acre, being mixed with dry earth for ease in application. On the latter estate, an untreated band was to be left down the middle of the plot.

The pH of the 3-ton per acre limed plots was tested in May, 1932, and the results were as follows:—

1 foot ..	7.2	3 feet ..	6.1
2 feet ..	6.2	4 feet ..	6.1

The results of these various experiments are very difficult to trace and there seems to be a likelihood that a file containing some of these may be missing. No conclusions are given in the Annual Reports of the Department.

The dressings in the manurial experiments were apparently maintained for two years only. There seems to have been no marked reduction in C.B.D., as might have been expected. Wilkinson visited the Maramura plots in August, 1934; no effects could be detected. Cottington came to the same conclusion in September, 1935. Observations were apparently maintained until the Sotik Experimental Station was closed down.

No further experiments on phosphatic or potassic fertilizers were made on the Sotik station, but an experiment to determine the effect of various levels of nitrogen was set up. It was a four-block, four-treatment randomized block experiment and each treatment was thus replicated four times. The treatments were:—

1. Cattle manure at 45.5 tons per acre, five *debbies* per tree scattered and then turned in in May.
2. Buckwheat planted in lines 2 ft. apart at 57 lb. per acre. Removed at harvest and another crop sown immediately.
3. Controls.
4. Grass dug in at ten tons dry material per acre.

Percentage variation in C.B.D. of plots having the same treatment were high, the highest difference being 7.49 per cent.

No statistically significant differences in yield or percentage infection with C.B.D. were detected during the three years this experiment ran, although there was a marked and statisticallly significant gradient of increasing C.B.D. attack across the experiment as a whole. It was concluded that "nothing in the way of applied treatments has materially altered the original susceptibility to disease arising out of some factor inherent in the situation of the bushes in the plantation".

In February, 1935, ammonium sulphate at 75 lb. per acre was applied to a plot, leaving a control strip across the middle. Further applications were made in May and in the same months the following year. No C.B.D. was present in 1935, but in 1936 both treated areas were slightly higher in C.B.D. than the control area: 18.5 and 15.6 per cent as against 13.3 per cent.

Zinc sulphate at 1 lb. per tree was spread on the soil beneath the tree canopy in February, 1935 and 1936 on a similar lay-out to the last. No C.B.D. was present in 1935. In 1936, the the treated plots gave 23.0 and 21.3 per cent C.B.D. as against 9.9 per cent on the control area. The same substance was applied as a 0.8 per cent spray to the foliage of trees in a similar layout in 1935. The sprayed plots averaged 21.3 per cent infection and the control 20.1 per cent.

In 1936, a final experiment to see if any minor element or other mineral deficiency was responsible for the disease was carried out. The layout was as before. The treated plots received in February ammonium sulphate at 75

lb. per acre, sulphate of potash at 120 lb. per acre, bonemeal at 100 lb. per acre, and 1 lb per tree of a mixture containing arsenic, boron, barium, bismuth, cobalt, chromium, copper, iron, mercury, iodine, lithium, magnesium, manganese, molybdenum, nickel, lead, thallium and zinc. In May, a further dressing of 75 lb. per acre of sulphate of ammonia was made plus one *debi* (30 lb.) of *boma* manure per tree. The treated plots had 29.3 and 14.5 per cent C.B.D. and the control 14.8 per cent. Thus in all these three experiments, the tendency appears for the treatments to increase attack by the disease.

During the life of the Kepchomo Experiment Station, no more attempts were made to relate C.B.D. to manurial treatments, with two exceptions. Manurial trials and experiments were laid down on Kepchomo, Savani and a number of private estates, but these were concerned with the effect on yield and not on C.B.D. attack.

In May, 1938, an experiment to test the effect of borax was laid down on Savani Estate, E.A. Plantations, Ltd. It was a randomized block layout with three treatments replicated four times, each block consisting of 25 trees. The treatments were Control, 5 lb. of borax per acre and 10 lb. of borax per acre. No differences were observed (presumably by eye only) and the experiment seems to have been abandoned the next year.

On the same estate, a final experiment to test whether high nitrogen feeding might encourage C.B.D. through an effect on the C/N ratio was laid down in May, 1938. It was a 5×5 latin square and in the first year had the following treatments: 0, 50, 100, 150 and 200 lb. per acre of ammonium sulphate applied in May. It was found by observation that the effect of the dressings was not sufficiently marked and it was decided that the following higher rates of application should be given: 0, 500, 1,000, 2,000, 3,000 lb. per annum, to be given in monthly doses. This scheme was followed until August, 1939, and was then discontinued owing to the outbreak of war. The doses actually given were thus: 0, 290, 583, 1,166 and 1,750. In both years, eye observations on the incidence of C.B.D. showed no increase over the control. In the second year, there was a marked effect on leafage. In January, 1940, this difference was no longer in evidence, but there was a marked decrease in Hemileia (leaf rust) on the treated plots.

The grassing down experiments, which were intended to produce low nitrogen conditions, may be mentioned here. There were seven unreplicated treatments on Kepchomo Estate in May, 1939, as follows:—

(1) *Paspalum dilatatum.* Complete cover.

(2) *Paspalum dilatatum.* In strips between trees both ways.

(3) Control.

(4) Leafage from (5) to be wilted and dug in continually.

(5) Napier grass in single rows between coffee trees in one direction.

(6) Kikuyu grass. Complete cover.

(7) Kikuyu grass. In strips between trees both ways.

The same design was probably used in a replication of the experiment on Savani Estate. Owing to a misunderstanding, the grasses at Savani were allowed to grow too vigorously and the trees suffered badly. No effects on C.B.D. were observed, however, but there was very little crop. The experiment was abandoned in December, 1949. The Kepchomo experiment was continued until the station was closed in May, 1944.

4. *Spraying*

Copper spraying was naturally among the first control treatments suggested. In the circular of December, 1922, [1] ½ per cent Carbide Bordeaux was advised, "Drake and Fletcher" spraying machinery and knapsack sprayers being distributed by the Department on loan. No controlled experiments were carried out for some time, but planters' reports published in January, 1925, [2] suggested that it was effective. It appears that in part the "effects" were due to a general decline in C.B.D. from the first year it was noticed and in part to the so-called "tonic" effect of copper spraying on the general health of the coffee.

The first definite trial arranged for copper spraying seems to have been that carried out by a planter on Jamji Estate, Sotik, in 1929, in which Ky-Bordeaux and a "Universal Spreader" produced by Cooper and Nephews were tested. Adjacent areas were to be sprayed with the Ky-Bordeaux plus spreader and with the normal Bordeaux mixture. Eye estimation of C.B.D. was used; no difference in the effects of the two sprays was observed.

Towards the end of 1929, a note by Trench suggests that spraying was not being found to

be a satisfactory control and in 1931 he was asking for spraying trials in the Sotik area to be part of a programme of investigation for a full time officer. Mr. Stone was appointed towards the end of that year and spray trials were carried out on three estates starting in September. These estates were Sotik (Fenwick), Kama Kosa (L. Packenham Walsh) and Mutarakwa (R. Mayers). The following sprays were used:—

1. Bordeaux made with hydrated lime.
2. The same plus Capex spreader.
3. The same plus lead arsenate.
4. Sulphur and soft soap emulsion.
5. "Texide" oil emulsion.
6. "Volk" oil emulsion.
7. Lime sulphur with Capex spreader.

The layout consisted of two sprayed plots separated by a control. On Kama Kosa, the plots were six rows wide and six trees long, at Sotik Estate they were 4×6 and at Mutarakwa 4×5.

Both the number of C.B.D. attacked cherries and the total crop was recorded for each tree individually. Unfortunately only certain interim results appear to have been preserved, and these only give the number of C.B.D. cherries picked in January, February and May-June. No figures for total crop are available. As the number of cherries with C.B.D. is in part a function of the crop on the trees and certain treatments are mentioned as having reduced the crop considerably, without figures for total crop, no correction for this factor can be made and only the effect of the treatments on the number of C.B.D. berries picked can be discussed. This will give little more than a tentative suggestion as to which treatments, if any, were really controlling the C.B.D. and in consequence giving increased crops.

The number of C.B.D. berries per bearing tree have been calculated by the writer for the three plots and those for the two sprayed plots averaged and expressed as a percentage of the numbers from the control plot. The results are given in Table 4. As a rough indication of degree of significance, if both the treated plots had lower (or higher) figures than the control plot, the percentages have been marked with an asterisk. Figures lower than 100 indicate the possibility of a degree of control whereas those above suggest the reverse. Of the various Lime Bordeaux formulæ without arsenate added, only once was a suggestion of control found, and in two earlier recordings there was no effect. With added arsenate there are three cases; in one of these in the previous recording there was increased C.B.D. It is possible that the apparent decreases in C.B.D. were actually due to decreases in crop from the effect of arsenate.

With Carbide Bordeaux increases in C.B.D. occurred in both the two trials, in the second there being a large increase in the first recording and a decrease in the second, the overall effect being an increase. As this spray normally increases crop, these increases may be the reflection of this, if the effects were real.

In both the two trials with Burgundy there was a decrease. This was large in the case of the half-yearly total on Fenwick's Sotik Estate and advantage has been taken of the individual tree recording to see if by comparing trees at random from one or other side of the control tree this effect was likely to reach statistical significance. The difference was found to be significant between the 0.1 and the 0.5 per cent probability levels, but considering that the position of the control tree could naturally not be randomized over the area, the result can only be taken as a suggestion that a real control effect was being observed. Burgundy spraying normally increases crop, so that this is a second point in favour of the conclusion that a real control effect was being obtained.

"Bouisol" showed a very slight suggestion of control. Lime sulphur gave a fair suggestion of a possible control effect, as did also sulphur and soft soap. The two "Sulsol" trials gave opposing results.

All the oil sprays, "Simsim", "Volk" and "Texide", gave apparent controls, some of the figures for the last two being very low. Stone, however, notes that both these sprays reduced the crop considerably and no doubt this explains the results. "Volk" produced abundant star-flowering and removed the bark from the trees.

The general conclusion would appear to be in favour of slight control by some of the fungicides tried, but that Carbide Bordeaux and the Lime Bordeaux did not appear effective. It is most unfortunate that the total crops are not to be found in the records, as otherwise the results of these very comprehensive trials would have been very useful in spite of the lack of a statistically valid lay-out.

During the life of the Sotik station, a number of spray trials were carried out and a large range of sprays tested,

TABLE 4

RESULTS OF SPRAY TRIALS IN SOTIK 1911—1932

		January			February		May–June		3 Months' Total
		F†	M	W	M	W	M	W	F
1. ½ per cent Lime Bordeaux —0·4 per cent Soft Soap	Lime Bordeaux sprays with various spreaders.	—	81·4	—	—	—	—	—	—
2. ½ per cent Lime Bordeaux —½ per cent Capex Spreader		—	—	103·3	—	99·0	—	58·6*	—
3. ½ per cent Lime Bordeaux —0·1 per cent Capex Spreader		90·1	—	—	—	—	99·6	—	124·6
4. ½ per cent Lime Bordeaux —0·1 per cent Capex Spreader	Lime Bordeaux sprays plus 0·1 per cent arsenate.	70·8	—	45·4*	—	52·7*	—	—	—
5. ½ per cent Lime Bordeaux —½ per cent Capex Spreader		—	—	162·0*	—	53·8*	—	—	—
6. ½ per cent Lime Bordeaux —0·4 per cent Soft Soap		—	—	—	114·0*	—	—	—	—
7. ½ per cent Carbide Bordeaux	Carbide Bordeaux sprays.	—	—	185·0*	—	136·7*	—	—	—
8. ½ per cent Carbide Bordeaux —½ per cent Capex Spreader		—	205·9*	—	72·3*	—	—	—	—
9. ½ per cent Carbide Bordeaux —0·1 per cent arsenate and 0·1 per cent Agral		—	—	—	100·8	—	—	—	—
10. ½ per cent Burgundy		—	—	—	—	—	—	81·4*	10·1*
11. 1:300 Bouisol		—	—	—	—	—	74·5	81·9*	74·8
12. 1:40 Lime Sulphur		100·5	148·7*	—	78·8*	—	—	60·6*	—
13. ½ per cent Sulphur—½ per cent Soft Soap		60·2*	—	92·5	—	16·7*	—	—	—
14. 1:300 Sulsol		—	—	—	—	—	41·3*	178·8*	—
15. ½ per cent Simsim Oil—½ per cent Soft Soap		—	—	—	—	—	27·3*	20·6*	—
16. 1:40 Volk		52·5*	57·1*	47·6*	117·3*	4·2*	—	—	—
17. 1:40 Texide		—	100·0	47·2*	—	14·5*	62·2*	1·84*	—

†F = Fenwick's Estate. M = Mayers'. W = Packenham Walsh's.

The following sprays were tried in 1933 [7]:—

1. Bordeaux mixture and 1 per cent linseed oil weekly from March to August.
2. Bordeaux mixture and 1 per cent linseed oil monthly from March to August.
3. Bordeaux mixture and 1 per cent linseed oil monthly from mid-May to mid-July.
4. Bordeaux mixture and 1 per cent linseed oil bi-monthly.
5. Bordeaux mixture and 1 per cent linseed oil bi-monthly neglecting cultural practices.
6. Bordeaux ½ per cent plus 1 per cent linseed oil in mid-March.
7. Bordeaux 1 per cent plus 1 per cent linseed oil in mid-May.
8. Bordeaux 1 per cent plus 1 per cent linseed oil in mid-March.
9. Bordeaux ½ per cent plus 1 per cent linseed oil in mid-May.
10. Bordeaux ½ per cent plus molasses (½ lb. to every 2½ lb. copper sulphate) monthly from mid-March to mid-August.
11. Bordeaux ½ per cent plus molasses (½ lb. to every 2½ lb. copper sulphate) bi-monthly.
12. Bordeaux 2 per cent plus 1 per cent linseed oil, monthly mid-March to mid-June.
13. Bordeaux 2 per cent plus 1 per cent linseed oil, monthly mid-May to mid-July.
14. Bordeaux 2 per cent plus 1 per cent linseed oil bi-monthly mid-March to mid-July.
15. Linseed oil-Whale soap emulsion, monthly mid-March to mid-April.
16. Linseed oil-Whale soap emulsion, by-monthly mid-March to mid-August.
17. Sulco VB, 1 in 50, monthly mid-March to mid-August.
18. Sulco VB, 1 in 50, bi-monthly mid-March to mid-August.

Each treatment was applied to a single plot of 5 × 12 trees of which the middle third was left as an untreated control. C.B.D. infected and sound cherry was picked separately at intervals and the number of cherries in each category was recorded for each tree. Sprays were applied by a "Drake and Fletcher Headland" pump at 200 lb. pressure.

C.B.D. infection was very low and the highest plot infection was 9.6 per cent. Treatments Nos. 1 to 3 and No. 12 showed no infection on treated or control areas.

In all, besides the treatments with nil infection on controls, there were seven with slightly lower rates on the sprayed plots and five with slightly higher and in no case of lower C.B.D. on the sprayed plot was the apparent reduction more than of academic interest.

Using the same procedure and lay-out, the following sprays were tried in 1934:—

1. "Shirlan A.G." plus "Agral 1". An organic fungicide containing salicylanilide.
2. "Palustrex copper compound". A copper product dissolved in oil.
3. 1 per cent Bordeaux plus sulphite lye, the latter substance being a spreader.
4. 1 per cent Bordeaux without spreader.

The sprays were applied on 10th May, 12th June, and 16th July. C.B.D. infection on the control plots ranged from 28 to 29.5 per cent and thus was remarkably even.

The results obtained for percentage infection are given in Table 5.

TABLE 5

	Treated	Control
"Shirlan"	28	29
"Palustrex"	27	29·5
Bordeaux plus sulphite lye ..	19	28
Bordeaux without sulphite lye	17·5	29

Even in the absence of a properly designed lay-out, since the control plots showed so little variation, it is evident that "Shirlan" and "Palustrex" were ineffective whereas Bordeaux with or without a spreader definitely reduced the amount of C.B.D. infection.

The increase in crop brought about by these three sprayings only amounts to about 10 per cent, however, which is hardly sufficient to justify the expenditure on the spraying.

Hemileia (leaf rust) was bad on the unsprayed plots and it was suggested that the control of C.B.D. might have been related to the control of this disease. Examination of the figures by the writer showed, however, that the control of Hemileia was not reflected in an increase in the total crop (including C.B.D. infected cherry). This, incidently, removes the possibility of the control of C.B.D. being an apparent one only and really connected with the higher crop which is often obtained from copper sprayings even in the absence of obvious disease.

In 1935 [9] two trials were carried out. In the first, two adjacent ¼-acre blocks of multiple and single stem coffee were sprayed on the

system which was reported to have been successful on "Savani" estate, Nandi. Adjacent ¼-acre blocks of multiple and single stem coffee were left unsprayed. The spray was 1 per cent Bordeaux plus 1 per cent linseed oil and was applied in January and May, this timing being the essence of the "Savani" system. The results are given in Table 6.

TABLE 6

	Multiple stem	Single Stem
Sprayed	4·3 % C.B.D.	9·1 % C.B.D.
Unsprayed	14·0 % C.B.D.	25·8 % C.B.D.

Thus infection was apparently reduced to about one-third in each case.

In a second similar trial, a "routine" spraying of ½ per cent Bordeaux mixture was given in March and July with the results given in Table 7.

TABLE 7

	Multiple stem	Single stem
Sprayed	11·2 % C.B.D.	13·6 % C.B.D.
Unsprayed	22·4 % C.B.D.	31·9 % C.B.D.

The infection was reduced to about one half in each case. The lack of replication and of a statistically valid lay-out, precludes reliable conclusions from being drawn, but it would appear that both systems reduce C.B.D. infection to a fair extent but do not produce a really satisfactory control. There is a slight suggestion that the earlier spraying was more effective.

In 1936, the final year of investigations at Sotik, the "routine" spraying trial was repeated, but a heavy hail-storm precluded observations being made. A "time of spraying" experiment was also set up. Two adjacent blocks of 11 × 16 and 12 × 16 trees on the multiple stem and single stem systems respectively were divided into six plots of equal size as shown in Table 8.

TABLE 8

Single Stem			Multiple Stem		
Jan. 9·2	Control 19·3	March 4·7	Jan. 2·1	Control 10·9	March 11·5
Mar. 18·7	Control 20·0	Jan. 3·2	March 11·2	Control 18·8	Jan. 2·9

The figures are the percentage of C.B.D. infected berries. The months named refer to the first spraying; two subsequent sprayings were given in each case in May and July. 1 per cent Bordeaux was used. A summary of the results is given in Table 9.

TABLE 9

	Single	Multiple	Whole Trial
First spray in January ..	6·2	2·5	4·4
First spray in March ..	11·7	11·3	11·5
Control ..	19·6	14·9	17·3

Once more there is evidence of control, though the experiment is vitiated by the systematic lay-out. There is also evidence that the early spraying produces a better control. This confirms the conclusions obtained on the "Savani" system in the previous year.

In 1937, spray trials were laid down on Kepchomo Estate, Nandi, but owing to the war these experiments were never written up properly and information on them is in consequence somewhat incomplete. In any case, it turned out that the lack of crop on this estate was not so much due to C.B.D. as to shy bearing under the cold moist conditions prevalent.

In one experiment two copper sprays, "Copper Cosmol" and "Cosmic Copper" were tried against 1 per cent Carbide Bordeaux applied either before the rains or after flowering and there was an unsprayed control. There were six blocks, divided into four 2 × 8 tree plots. The treatments were randomized. At the end of the first year, no differences in C.B.D. infection could be seen by eye, the control plots being as badly infected as the sprayed. Yields were apparently recorded but the records are missing. According to Green (in a letter) copper spraying had produced increased yields. In 1940, Perenox and another new spray were substituted for the colloidal copper ones, but the station was closed down before results were obtained.

In the second experiment, the effect of time of application of Bordeaux was tried. 45 × 45 tree blocks were apparently used and each treatment was duplicated. Three treatments were given: the first consisted of spraying two to three weeks after the main flowering, and again some six weeks to two months later. The second was spraying just before the main rains were anticipated and again some six weeks later. The third treatment was a control of no

spraying. There is no record of the results of this experiment.

Other small observational trials were conducted on estates, but there appear to have been no outstanding results.

Although many of the trials described above were not sensitive and were open to serious criticism as to design, so many have been carried out that one may draw certain conclusions. It would appear that none of the many substances tested brought about effective control of the disease above, say, 80 per cent reduction in the number of diseased berries produced. On the other hand, there is little doubt that some degree of control is exercised by most fungicidal sprays and this indicates the basically fungal nature of the disease and is an important conclusion to bear in mind should any further investigation of the disease be attempted.

There is evidence, too, that control is increased with increasing frequency of spraying, another point of considerable theoretical, though not practical, importance. It suggests that a completely efficacious fungicide would completely control the disease. As it may be assumed that nothing less than an almost complete and permanent cover of the developing fruit would be required, and since very thorough spraying with ordinary fungicides does not produce a sufficient control, it would seem that only something completely new in method of action is likely to succeed. An example of such action would occur should an efficient systemic fungicide be developed, which would be absorbed by the plant and render the tissues of the latter unsuitable for fungal invasion.

5. *Selection of Resistant lines of Coffee*

It seems to have been recognized quite early in the history of C.B.D. that certain trees showed a degree of resistance to the disease. The first mention on the files appears to be by McDonald in a letter to Harland Frank in October, 1925, where selections of seed from resistant trees by the then Plant Breeder were mentioned as being under way. It may be interpolated here, that the observation that infection varies very considerably from tree to tree may have been in part the basis of the idea. In practice, what is a resistant tree one year may well be heavily infected the next and a number of years' observations are needed to be sure that one is really dealing with a case of true resistance. The early attempts at selection were merely by eye and possibly based only on a single year's observation and at the best only on a memory of previous performance.

Little systematic work appears to have been carried out, but some selection appears to have been made by various planters. In 1932, McDonald mentions in a letter that bronze-tipped types were more resistant than green-tipped and the resistance of Daly's "Blue Mountain" coffee imported from Jamaica is mentioned.

In 1931, Dr. Storey visited the Sotik area at the invitation of the Department of Agriculture. In his report he advocated that more attention should be given to the breeding and selection of resistant lines since the methods of direct control at that time being tested might not prove to be effective and in any case control by the use of resistant plants is always to be preferred to the use of (usually expensive) artificial methods. As the selection of lines pure for resistance might involve many years of breeding, he advocated the study of vegetative propagation from trees selected for resistance, either by cuttings or by grafting. Selection of individual trees should be made from records of resistance over a number of years and vegetatively reproduced progeny should similarly be tested, as an accident of position, development or treatment might be the reason for apparent resistance in an individual tree. Having obtained resistant types, rehabilitation of existing estates could probably be most rapidly carried out by stump grafting.

In consequence, early in 1932, Stone was instructed to carry out preliminary investigations on vegetative propagation, including methods of obtaining cuttings and of making grafts. This work was continued by Mr. Cottington when the Sotik station was opened. Attempts at obtaining cuttings by use of sand in a solar propagator were completely unsuccessful. Cuttings were however obtained by another method which consisted of stumping an old tree and allowing suckers to come away at the base. When 1½ ft. to 2 ft. high they are either ring-barked or half cut through near the base. A 4-gallon petrol tin open at both ends in placed over the stump and suckers and filled with soil. Roots grow at the point of ringing or cutting and eventually the cutting may be separated entirely from the mother plant.

Successful seedling grafts were obtained using the cleft technique at the point of

change from green to brown wood. Grafting seedling scions on to old established coffee was also successfully carried out by cleft-grafting, approach-grafting on to suckers or by inarching either into suckers or into the stumps of the old trees.

Although some selection work on old established coffee appears to have been carried out, the main emphasis on the Sotik station seems to have been on testing varieties of coffee either imported from other parts of the world or locally selected by the Department for other characteristics or by planters. Blocks of these varieties were established from seed and the first report on their behaviour is given in the 1936 report [10] and is as follows:—

	Per cent of crop infected
Columnaris	no crop
Padang	11.7
Kenya selected	13.6
Kenya selected (second plot) ..	33.7
Bourbon	16.1
Guatemala	8.1
Kent's arabica	6.8
Kent's arabica (second plot) ..	17.9
Plateau Bronze (a local selection)	6.8
Plateau Bronze (second plot) ..	9.2
Blue Mountain, imported seed	3.1
Blue Mountain, imported seed (second plot)	8.2
Blue Mountain local seed ..	5.3
Blue Mountain local seed (second plot)	4.4

The varieties on trial, but which had not yet produced crop were Gallio (a local selection), Harar, Mysore and Amfillo.

All the varieties producing crop are seen to have been infected, but Blue Mountain had the least; it may thus be considered resistant, but not immune. The variation shown to exist between duplicate plots does not justify any further remarks as to relative resistance, though there does appear to be some evidence for resistance in the Plateau Bronze.

Mysore appears to have been considered as a resistant type from observations of this variety growing on estates. There seems to have been some doubt on the point, however, but whenever reports of its lack of resistance were investigated, the coffee was always found to be of mixed type due to locally obtained seed.

A large range of grafted trees were established as is shown by the following list:—

(a) Nursery grafts.

1. Three types of French Mission selected for different degrees of cold susceptibility on the same Blue Mountain rootstock.
2. Resistant types of French Mission on to Blue Mountain.
3. Jacksons hybrid on to Gallio.
4. "Guy II" a resistant local tree on to Gallio.
5. Resistant Series A on to Gallio.
6. "Guy III"another resistant local tree on to Gallio.
7. Susceptible French Mission on to Kinowa (Robusta) rootstocks.
8. Blue Mountain (imported) on to Kinowa (Robusta) rootstocks.
9. Susceptible French Mission on to Kinowa (Robusta) rootstocks.
10. Gallio on to Kinowa (Robusta) rootstocks.
11. Susceptible French Mission on to No. 9 Robusta rootstock.
12. Gallio on to No. 9 Robusta rootstock.
13. Susceptible French Mission on to "Enoka" Robusta rootstock.
14. Blue Mountain (imported) on to Series A rootstocks.
15. Susceptible French Mission on to Blue Mountain (local seed).

(b) Grafts on to established French Mission

1. Kents.
2. Amfillo.
3. Coffea eugenioides.
4. Blue Mountain (local).
5. Harar.

Although the Sotik station was closed in 1936 as far as other experiments were concerned, recording of the variety and grafted trees was continued until 1942. Unfortunately, no detailed report on the results was ever produced, though the general conclusion was that only the Blue Mountain variety showed any real promise.

Some notes made by E. C. M. Green in 1938 and 1939 are indicative of the final results. Columnaris remained a shy bearer, but one tree out of three grafted on to Series A rootstocks flowered well and a rootstock effect is possible. Padang is a Blue Mountain-like type which cropped quite well and was resistant to C.B.D. Kenya Selected was very susceptible.

Bourbon crops well but loses most of it with the disease. Kents was vigorous, but very susceptible to C.B.D. Plateau Bronze is very mixed and only the types resembling Blue Mountain were resistant. Gallio is a very mixed type and all were susceptible. Harar was extremely susceptible to C.B.D, Cercospora leaf spot, leaf disease and die-back and was completely useless in the area. Amfillo was very variable, but some appeared to be fairly resistant to C.B.D. Blue Mountain, both Daly's and imported, retained their resistance, and good crops were recorded.

Some notes made by Mr. Cottington in 1940 on varieties which were not in bearing at the time of Green's visit, are on the files. Selection W.S.II made by C. Thorald on W. Wreford Smith's farm on Elgon showed a light C.B.D. infection on some trees in its first crop. Geisha, Amfillo, and imported Mysore all showed light C.B.D. infections. At the same time Blue Mountain both imported and local showed light infection, whereas Bourbon, Gallio and French Mission all showed heavy infection.

In 1941, Cottington notes that French Mission and Bourbon on Blue Mountain were the worst attacked by C.B.D. Blue Mountain and Padang were outstanding in their resistance.

As regards the grafts, Green reported that all the scions appeared to maintain their characteristics and no effect on C.B.D. susceptibility could be detected. With the exception of the Robusta rootstock which caused a slowing down of growth, no obvious rootstock effect could be detected. No critical observations could be made on yield as no experiments were designed to this end.

In 1935, an experiment was set up to test methods of conversion of a susceptible French Mission plantation into one of resistant Blue Mountain. It consisted of five adjacent plots of 12×6 trees each on the multiple-stem system. The treatments were as follows:—

(*a*) Control.

(*b*) Interplanted on the quincunc system with Blue Mountain seedlings (imported seed). Old trees allowed to remain until after the 1936 crop.

(*c*) Old trees dug out after the 1935 crop, and replanted with Blue Mountain seedlings in the same positions relative to the old trees as in B.

(*d*) Old trees cut back to initiate a new cycle of comparable age with the seedlings in B and C.

(*e*) Old trees cut back and inarched with Blue Mountain seedlings.

In 1939, Green reported that there was little difference in growth of interplants whether the old trees were removed or not at first. A modification was made in which sections of the B plots had the old trees removed in successive years. This showed that in the later stages, better growth was obtained by removing the old trees. The suckers in treatment D grew very much faster than the interplants or grafts, as might be expected as they did not receive the set-back of being capped or bent over. The inarched seedlings were more advanced than the interplants. The conclusion would appear to be that inarching produces the least loss of crop and the most rapid changeover.

At the Kepchomo station, Nandi, the work on methods of grafting and selection and trial of types for resistance to C.B.D. was continued. A search was made of the surrounding coffee estates for C.B.D resistant material, but nothing appears to have been found that was any better than Blue Mountain.

A variety trial on multiple and single stem, shaded and unshaded, but unreplicated was laid down to test the following varieties:—

1. Amfillo.
2. H.3.B. } "Climatological" selections
3. J.2.D. } made by C. Thorald on Mt. Elgon.
4. 62.
5. Geisha.

In 1944, when Kepchomo was closed down, a variety trial was planted at the top of Savani Estate, which was a much more satisfactory locality for testing C.B.D. resistance, as here there was no trouble in getting a crop set, but it is usually very severely reduced by C.B.D. This plot is still in existence, and it is hoped to make it the basis for further selection work. The varieties being tested are Geisha, Amfillo, J.2.D., Dalle-Alghe (Melville), Dalle (Green), Gimma-mbuni, Gimma-Galla-Sidama, Dalle (Symes) I, II and III, Rume-Sudan, Barbuk-Sudan and Dilla (Melville). They include a number of new types from indigenous coffee growing wild or cultivated in Abyssinia and the Sudan. J.2.D. was a climatological selection made by C. Thorald of which the early crop at Kepchomo showed complete absence from

C.B.D. attack. It also had some resistance to Elgon die-back.

A number of coffee varieties have been on trial at the Kitale station and some data as to their reactions to C.B.D. have been obtained. Kitale is not outstanding in the severity of its C.B.D. attacks, but it is in such an area that a better idea of degrees of resistance and susceptibility may be obtained than in a locality where the attack is more intense. The following varieties have been tried: Amfillo, Geisha, Hara, Blue Mountain Columnaris, A 47, A 72, A 81, SL 28, Series L, Series C, DR 1, SL 34, SL 2, SL 3, SL 9, SL 17, SL 14. Scion material of SL 1, SL 3 SL 6, SL 9, SL 17, SL 18, SL 19, and SL 34 was also sent to Kitale.

Mr. Cottington reports that although this material has not been carefully observed for reaction to C.B.D., in his experience all Series A types whether from the Scott Laboratories or Kapretwa (Elgon) have been attacked. The broad-leafed types such as SL 1, SL 2, SL 3, SL 6, SL 9, SL 14, SL 28, and SL 34 are more attacked than the rest and SL 14 is particularly susceptible, losing all its crop every year with the disease. Amfillo and Geisha have little if any C.B.D. at Kitale, but Harar, as elsewhere, consistently loses all its crop.

A block of 100 trees of Blue Mountain coffee has been individually recorded for a number of years and this should provide material for further selection of this type in order to obtain improved yield, quality and resistance.

In the Belgian Congo, selection of the local coffee for resistance to C.B.D. was carried out with the production of several types collectively designated "Local Bronze" [16].

In 1941, native-grown Blue Mountain coffee at 6,300 ft, near the Murumba pulping station, Kitutu location, S. Kavirondo developed a disease which attacked the cherry a little while before it was ripe causing the production of a type of "mbuni".* From cultures made on the spot, the typical form of *Colletotrichum coffeanum* associated with C.B.D. was obtained. The disease may be considered intermediate between Brown Blight and C.B.D. and has been referred to as Kisii Berry Disease. The effects are quite serious as a large proportion of the crop turns to "mbuni", but not so serious as C.B.D. proper where the attacked berries usually contain no bean, instead of the small but undamaged bean found in Kisii Berry Disease. The trees were four years old when first attacked. In 1943, a visit was paid by the writer to the area and also to other C.B.D. areas where Blue Mountain coffee was being grown. In the Sotik area, considerable damage to crop on Blue Mountain coffee had occurred due to the Kisii form of the disease; the normal C.B.D. form of attack was also present, but to a lesser extent. In all cases, the coffee affected lay above 6,000 ft.

In the Kisii area, the disease was only found at two places, the original locality at 6,300 ft., and another at 5,800 ft., although there was plenty of coffee growing at intermediate altitudes. The latter locality however, had typical "tight" growth, and was believed to be exceptionally cold. It was concluded that Blue Mouuntain coffee was still to be considered markedly more resistant to berry disease than other types, but that at high altitudes this resistance was not sufficient to counteract the extremely favourable conditions for the disease. It was considered that the use of Blue Mountain coffee allowed the ceiling up to which coffee could be more or less safely cultivated without fear of C.B.D. to be pushed up some 200 ft.

As altitude effect varies with locality, it is not possible to give a precise height below which C.B.D. attack is precluded, but it may be taken as a rough guide that for French Mission below 5,500 ft. is safe and for Blue Mountain 5,700 ft. Above these heights, coffee should be planted in the first place experimentally only for the first four or five years. Above 6,000 ft. planting of any variety of coffee in the West Rift area should only be undertaken with the greatest caution, though even above this height it is possible to find places where the climate is such that C.B.D. may not occur.

The results of the investigations of resistance to C.B.D. thus indicated that considerable material exists which shows a degree of resistance to the disease. The ordinary French Mission type itself has been shown to have forms with a degree of resistance, whereas such varieties as Padang, Mysore and pre-eminently Blue Mountain also possess resistance. No variety is immune and only Blue Mountain has sufficient resistance for it to be considered worth while for commercial planting. With the exception of a degree of selection carried out

* Dried-out berries, usually, as in this case, the drying out occurring without previous ripening.

on French Mission (and similar work carried out in the Congo on the plantation coffee type there), little selection for further resistance, improved yield and quality appears to have been carried out in the past, though this would appear to be the logical next step to be taken and in fact work of this nature has now been put in hand by the Coffee Services. As part of a long-term programme, breeding and hybridization should also be undertaken. Such work, however, might not give any results for a long time and offers no prospect of an early solution to the problem.

6. *Present Investigations*

During the war, all investigational work on C.B.D. eventually came to an end. Most of the areas where the disease was serious went out of production, partly due to the disease, partly due to the fact that these areas were really unsuited for coffee growing from other causes. The only palliative measure, the growing of Blue Mountain coffee, did not appeal to most planters at this time, and there was doubt as to whether in the long run, the variety would maintain its resistance, a doubt as will have been seen from the last section, was to be shown to have a measure of justification. With the increase in interest in coffee due to high prices, and with lowered European production, interest in West Rift coffee has received a stimulus with the result that the problem of C.B.D. has once more come to the fore. The first necessity in renewed investigations into the disease was a thorough survey of past work and this resulted in the present summary.

Although past investigations had not suggested that control of the disease by a fungicide was likely to be successful, new fungicides had come onto the market and it was considered worthwhile to test some of these. In any case, the point as to whether a fungicide was able to control the disease even to a minor degree has never been tested in a validly designed experiment and information on this point might determine future attempts at controlling the disease, especially should an efficient systemic fungicide be discovered. In consequence, a small experiment has been set up at Kitale using the very susceptible SL 14 variety grafted on to Blue Mountain rootstocks. Five treatments have been given: control, spraying with Perenox, Mercury Phenyl Fixtan and Tulisan in March, May, July and September and spraying with Perenox in July and September. The layout is a latin square with two trees per plot.

The most promising, but at the same time, slowest line of attack is by further selection of resistant varieties. A block of 300 Blue Mountain trees has been individually crop recorded for eight years at Kitale. These results will be analysed and good cropping trees with good quality coffee selected and multiplied up by vegetative propagation for further testing and selection.

The variety trial on Savani Estate, Nandi, is to be rehabilitated and when it comes into bearing, which should be within the next two years, any promising types will be selected, multiplied up, tested and further selected for yield and C.B.D. resistance.

A survey of the extent of loss of crop on existing West Rift coffee is being undertaken.

Conclusions

Since McDonald was able to produce the disease by inoculating wounded cherries with the strain of *Colletotrichum coffeanum* associated with diseased berries there seems little doubt that this fungus is the fundamental cause of the disease. The fungal nature of the disease is also confirmed by the results of the large number of spray tests in which a degree of control of the disease has been produced. The strict relation to climate and the very large variation in degree of attack on individual trees within an attacked area, a variation which is only partly controlled by permanent resistance, since a tree may be apparently resistant one year and susceptible the next, suggests that variation in the amount of inoculum may be a rather minor factor affecting the distribution and intensity of attack of the disease which is principally controlled by climatic variations and variations in the physiological state of the tree. Climate may, indeed, act rather through its effect on the physiological state of the tree than through any direct effect on the fungus, and it may be due to this effect, which would depend on an integration of climate over a period, that the detailed investigations of the relation of climate to the disease have not been very successful. It would appear that only through the use of controlled environment chambers away from a C.B.D. area is any real progress in elucidating the nature of the climatic control likely. As regards the nature of the physiological control, little investigation has been carried out, but it would appear that there is no evidence for any effect of nitrate nutrition, carbohydrate status or the ratio of the two. Nor is there any suggestion that a

deficiency in major or minor nutrient elements plays any part. The only substantial clue appears to be that vigorous trees are often badly attacked as are also vigorous varieties of coffee such as Harar. It is interesting to note that the latter variety produces in both East and West Rift areas large broad leaves, whereas Blue Mountain and other resistant types have small narrow leaves in the drier East Rift areas, but broader, larger leaves in the West Rift, which are equivalent to the average type of leaf produced by French Mission in the East Rift. The leaves of French Mission are also larger in West than East Rift areas. In fact, the degree of resistance to C.B.D. might be a function of succulence and cell size, which are both affected by climate and variety. A second consideration is that bronze tipped types appear to be more resistant than green tipped. The resistance to "cold" damage is also greater with the bronze tip types and the relation of C.B.D. to temperature is perhaps significant in this respect.

Further evidence for the effect of the physiology of the bush on the disease is to be found in the observation that young coffee apparently does not suffer from attack as much as old, the same applying to young suckers from a multiple head tree. These observations are in need of rigorous checking however. The different susceptibility of crops from different flowerings may be due to physiologic differences. It would also appear that reduction of crop by stripping may reduce the percentage of C.B.D. attack. This may be a physiological effect, but might also be due to a reduction in inoculum. The possibility that heavy cropping trees are worst attacked might also be due to a build up of inoculum rather than to exhaustion of some nutrient, whose presence confers resistance on the crop.

If McDonald was right in considering that other forms of *Colletotrichum coffeanum* than the one isolated from diseased berries are not responsible for the disease, one is left with the problem of where the inoculum comes from at the beginning of a new season.

The spores of the fungus are thin-walled and normally distributed by rain splashing. They die rapidly if subjected to desiccation. Infection is therefore unlikely to persist in spore form, unless a perfect stage exists which is at present unknown and which could produce air-borne resistant spores. The possibility that the so-called chlamydospores might be able to cause infection and also retain their vitality for a considerable period should be investigated.

The author's investigations at Nandi did not show the C.B.D. form of the fungus to occur on the plant immediately previous to an attack of the disease, though many other, and sometimes closely allied forms were abundant on all the tissues of the plant. He also showed, at Nyeri, that during an attack of the disease the virulent form of *Colletotrichum coffeanum* associated with C.B.D. formed latent infections on the leaf. If this is possible, why was this form not found on leaves in Nandi? *Colletotrichum coffeanum* has been shown to be an extremely polymorphic and variable organism.

McDonald found that mutations frequently occurred. The writer has shown that different forms are associated with different tissues. The hypothesis is put forward that the virulent form of the fungus comes into being due to the reaction of coffee tissues physiologically suited to attack on the less pathogenic forms of the organism. Since the other forms of the organism are extremely abundant on coffee tissues of all types and abundant sporing material is present on the bark of twigs and trunks during wet weather, such an hypothesis would account for the extreme difficulty which has been encountered in attempts to control the disease by fungicides or "orchard sanitation". If physiologically susceptible tissue is needed before the fungus can develop into a virulent type, some understanding of why no sign of the disease has hitherto occurred in the main East Rift area may be obtained.*

With regard to climate, there seems no doubt that the disease is associated either with relatively wet areas or those where high humidities are the rule (e.g. Nyeri). This factor could easily be acting directly on the growth and especially the sporing and distribution of the fungus, but as seen above may perhaps, in actuality, be working indirectly via a physiological effect on the plant.

From a superficial examination of the data, there would seem little doubt that low temperatures are associated with the disease, as evinced by the general relation with altitude and the especial susceptibility of trees in hollows and places where cold air accumulates. How-

* The recently reported case of C.B.D. in Upper Kiambu in the main East Rift area is interesting in this respect since it followed a prolonged period of rainy weather when some rain fell almost every day for over two months. There was also a very low number of hours of sunshine which presumably led to low temperatures.

ever, it must be remembered that low temperatures are strongly correlated with high humidities, so that the apparent relation to low temperatures might really be to the high humidities which usually accompany them. However, the observation that under certain conditions the removal of shade appears to favour the disease, a factor which increases the diurnal temperature range, and that after hail storms disease attack is stimulated, but in parts of the berry unwounded by the hail, suggests that temperature may be having a direct effect. The disease also seems to be at its height in the dullest, coldest and wettest months of the year.

Soil factors, although at one time thought to be most important, have been very thoroughly investigated and there is no evidence that mineral nutrition with either major or minor elements has any effect on the disease.

The very numerous spraying trials carried out have shown that whereas most fungicides may control the disease to a certain extent, none of them are sufficiently efficient to be an economic proposition. The fact that control is increased with frequency of spraying suggests that a completely efficacious fungicide might be able to effectively control the disease. Only an efficient systemic, if such were ever produced, seems to hold out much hope of direct control of the disease.

Indirect control via the use of resistant varieties holds out some hope of success and relative resistance has been found in a number of varieties. Of these, so far, Blue Mountain is by far the best, but the resistance does not reach as high a level as could be desired, nor is the quality and yielding capacity as high as it might be. Further selection of this and other varieties, followed by breeding work, is the line most likely to result in real progress in the control of the disease.

There are a number of outstanding problems presented by this disease which should be investigated should it be considered worth while devoting any considerable amount of time to further work on it. Such investigations however, would be very time-consuming and it would seem doubtful whether even if leading to better methods of control, which seems only a remote possibility anyway, they would be justified by the extra coffee which would become available from the present areas of coffee-growing affected. It must be remembered that in these areas, even if the menace of C.B.D. could be removed altogether, it is doubtful whether very much higher yields would be obtained, as production would still be affected by such things as shy bearing, berry fall, hail, etc., which limit the yielding capacity of many of the coffee estates affected by C.B.D. However, it is perhaps worth while here to point out some of the more important lacunæ in our knowledge of the disease.

Firstly, on the mycological side, a further investigation of the parasitism of all forms of *Colletotrichum* on coffee and the effect on their morphology of the tissues in which they develop might lead to a much better understanding of the disease. It may be possible to carry out some work along these lines in connexion with investigations on latent infections and "tonic" sprays. The method by which the infection passes from one crop to the succeeding one is unknown, and the hypothesis that infection arises from the other forms of *Colletotrichum* on the bush should be checked. In conjunction with this a properly designed trial of the effect of having a complete absence of fruit on the trees for at least a month in the year would be valuable.

A full investigation of the effect of climate might lead to useful results, but it seems likely that the use of environment control chambers would be the only satisfactory method and it would be necessary to work out methods of producing artificial infection in the laboratory away from areas where the disease occurs naturally.

A knowledge of the effect of the physiology of the bush on the attack of the disease is obviously necessary for a satisfactory understanding of the disease, but would be likely to prove to be an extremely long-term and difficult project with a considerable possibility of producing little definite evidence after even prolonged investigation. First steps in such an investigation should be the confirmation of the idea that young suckers are less attacked than old and that reducing competition between developing berries reduces attack. An attempt at finding out the causes of resistance would have to be made and the "succulence" hypothesis investigated.

It may be concluded that such investigations could easily occupy several research workers several years.

Summary

1. An historical summary of the past investigations on C.B.D. is presented. The attack developed suddenly in 1922 without any

previous definite record of the disease. Neglect of the coffee was at first blamed and later soil deficiencies. Spraying with copper containing sprays was advised, but was eventually found not to produce an economic control. Early investigations were mainly confined to the mycological side, but in 1931 an officer was appointed to work in the field in the Sotik area. With the establishment of a sub-station in Sotik, work on the disease reached its maximum from 1933 to 1936. With the failure to find any really satisfactory control except the use of resistant varieties, much coffee was abandoned in Sotik and the sub-station was virtually closed in 1937 except for recording of variety trials. Work was, however, transferred to Kepchomo sub-station, Nandi, but no major developments ensued and as the station was found to be unsuitable, it was closed in 1944. The disease was reported from the Belgian Congo in 1938, and the experience of investigators there has been very similar to our own. In Kenya the disease is confined to the West Rift with the exception of a minor outbreak at Nyeri, and a small infection in Upper Kiambu which has just been reported (June, 1951).

2. A form of *Colletotrichum coffeanum* was early found to be associated with the disease and has been shown by investigation of wounded cherry to reproduce the symptoms. *Colletotrichum coffeanum* has been shown to cause very abundant infections of all tissues in coffee, whether dead or alive; in the latter it is present in latent form. The form associated with C.B.D. could not be found in any coffee tissues examined in February when the disease is absent in the field. It is postulated that this form is developed from the other forms only when susceptible berry tissues are available.

3. C.B.D. normally only attacks coffee in the higher altitude range, 5,500 ft. being considered, on the average, its downward limit in the West Rift areas. It is associated with cold humid conditions and in marginal areas is usually found in hollows and places where cold air accumulates. Evidence is given which suggests that low temperatures *per se* influence the attack of the disease. Although meteorological observations were frequently made and much data accumulated, no precise definition of the meteorological conditions necessary for the disease has ever been produced. Hail has been held to initiate an attack.

The author postulates that whilst climate does play an important role in determining the distribution of the disease, the physiology of the coffee bush may be the key factor and in part climate may work through its effect on this rather than directly.

4. Soil deficiencies were once held to be a likely cause of the disease, but the numerous manurial experiments carried out failed to detect any effect of major or minor ("trace") nutrients and it is unlikely that the disease is associated with any soil deficiency or condition.

5. The degree of attack of the disease in the field varies very considerably from tree to tree, but this variation is only in part caused by permanent resistance of certain trees, and it would appear that the physiological state of the tree is an important factor.

Poor growing conditions have not been found to be associated with the disease, which may attack very vigorous coffee. The production of vigorous wood, however, counteracts the effects of the disease by producing a bigger crop. It is possible that vigorous trees are, in fact, worse attacked.

The few attempts at correlating the degree of attack with the chemical composition of the tree have not been successful. Numerous attempts at influencing the C/N ratio by supplying nitrates or by reducing them by weed competition, the digging in of green manures, etc., have not produced any effect on disease attack.

There is some evidence that young trees and young suckers on old trees are more resistant. There is fairly good evidence that reducing the crop leads to a lower degree of attack, but the possibility in both these cases that the level of fungal inoculum is reduced must not be overlooked and so far has not been tested. There is also fair evidence that, in Sotik the long rains' crop was less affected than the short rains. Confining the crop to the long rains flowering would not be a practical means of control.

6. Very numerous tests of a large range of fungicides have been carried out. Sprays used include various Lime Bordeaux formulations at ½ per cent, 1 per cent or 2 per cent with various spreaders and stickers such as soft soap, Capex spreader, linseed oil, molasses, sulphite lye, Agral and sometimes with the addition of lead arsenate, ½ per cent Carbide Bordeaux with and without Capex spreader, Ky-Bordeaux, ½ per cent Burgundy Mixture, Bouisol, Lime Sulphur, Sulsol, Simsim Oil and soft soap, Volk, Texide, linseed oil-whale soap emulsion, Sulco VB, Shirlan A.G. plus Agral I,

Palustrux copper compound, Copper Cosmol, Cosmic Copper, and Perenox. A degree of control with many of them has been demonstrated, but even the best timings and most frequent applications tried have produced an insufficiently high level of control and there is no doubt that unless a completely new type of fungicide is produced (such as an efficient systemic) economic control of the disease by spraying is unlikely to be obtained. Further testing of fungicides however, is being carried out at present, Perenox, Phenyl Mercury Fixtan and Tulisan being used.

7. Resistance to the disease has been found to be possessed by certain types of French Mission coffee, the Padang variety, possibly Mysore, selections (Local Bronze) of the local coffee around Kivu, Belgian Congo and especially by the Blue Mountain variety originally imported from Jamaica. No immune variety has been found. A number of varieties, many of which are from seed imported from Abyssinia during the war are still under test. Resistance seems to be associated with narrow-leaved, bronze-tipped types. Exceptional susceptibility is possessed by the Harar, and SL 14 varieties. The resistance of a scion does not appear to be subject to rootstock effects. Grafting resistant scions on to susceptible rootstocks is thus a feasible method of converting a susceptible plantation and has been shown to be quicker than replanting. Blue Mountain coffee is not immune to the disease; but its use allows coffee to be grown safely some 200 ft. higher than would be possible with French Mission coffee. At higher altitudes, less loss is sustained and the disease tends to attack later and in the form which has been called Kisii Berry Disease. The variety, Blue Mountain, is being selected in order to improve its quality, yield and resistance.

REFERENCES

[1] "Coffee Berry Disease", by J. McDonald. Mimeographed circular of 2nd December, 1922.

[2] "Coffee Berry Disease", by J. McDonald, *East African Standard*, 3rd January, 1925.

[3] "Coffee Berry Disease (*Colletotrichum coffeanum* Noack var.)", Department of Agriculture, Kenya. Mycological Leaflet No. 4, by J. McDonald. No date (between 1930 and 1932?).

[4] "A Preliminary Account of a Disease of Green Coffee Berries in Kenya Colony", by J. McDonald. *Trans. Brit. Mycol. Soc., II*, 145, August, 1926.

[5] "Notes on Diseases of Coffee in Kenya", by J. McDonald. Bulletin No. 7H of 1929, Department of Agriculture, Kenya.

[6] "The Major Coffee Diseases", by J. McDonald. Bulletin No. 20 of 1932, Department of Agriculture, Kenya.

[7] "Report of Committee on Coffee Berry Disease", Bulletin No. 3 of 1934, Department of Agriculture, Kenya.

[8] "Progress Report on Coffee Berry Disease—Report on Investigations and Observations during the period May, 1934, to September, 1935, inclusive", by J. McDonald. *Coffee Board of Kenya Bulletin*, November, 1935, p. 10.

[9] "Final Report on Coffee Berry Disease Investigations in 1935", by J. McDonald. *Coffee Board Bulletin II*, 74, April, 1936.

[10] "Report on Coffee Berry Investigations in 1936", by J. McDonald. *Coffee Board Bulletin III*, 30, February, 1937.

[11] "Coffee in Kenya", edited by J. McDonald. Published by Department of Agriculture, Kenya, 1937, pp. 151–164.

[12] "The 1936 Coffee Berry Disease Questionnaire", by J. McDonald. Published ?.

[13] "Kepchomo Experiment Station", by G. J. L. Burton. *Coffee Board Bulletin III*, 82, May, 1937.

[14] "Observations phytopathologiques à la Station de Mulungu en 1938", Rapport Annuel de l'INEAC pour l'exercise 1938, 2nd partie, pp. 117–128, 1939.

[15] "On the Conidial Fructifications of *Glomerella cingulata* (Stonem), Spauld et V. Schr. (Sphaeriaceae)", by F. Hendrikx. Commun. Inst. Nat. Etude, Agron. Congo Belge, Recueil I (Hors. Série), pp. 12–15, 1943.

[16] "Rapport pour les Exercises 1940 et 1941", INEAC, Congo Belge.

[17] "*Colletotrichum* ou *Antestia*", par F. L. Hendrikx. Inst. Nat. Etude, Agronomique Congo Belge. Série Sci. 22, pp. 10–16, 1942.

[18] "Latent Infection in *Coffea arabica*, L.", by R. W. Rayner, *Nature, 161*, 245, 1948.

References in the Annual Reports of the Department of Agriculture, Kenya

[19] Annual Report for 1923, p. 82.

[20] Annual Report for 1924, p. 107.

[21] Annual Report for 1925, p. 33k.

[22] Annual Report for 1926, p. 154.

[23] Annual Report for 1927, p. 194.

[24] Annual Report for 1928, p. 193.

[25] Annual Report for 1929, pp. 521 and 467.

[26] Annual Report for 1930, pp. 210 and 224.

[27] Annual Report for 1931, pp. 146, 163 and 119.

[28] Annual Report for 1932, pp. 124 and 152.

[29] Annual Report for 1933, pp. 146 and 207.

[30] Annual Report for 1934, p. 25.

[31] Annual Report for 1935, p. 2.

[32] Annual Report for 1936, p. 2.

[33] Annual Report for 1937, Vol. II, pp. 4, 31 and 41.

[34] Annual Report for 1942 (not published; on Department files only).

[35] Annual Report for 1949, Vol. II, p. 45.

FIG. 1.—Coffee branch showing berries attacked by Coffee Berry Disease. In the terminal quarter there are sound berries, in the next quarter there are mainly partially attacked berries, whereas below them completely dried out, dark brown diseased berries can be seen.

FIG. 2.—Coffee berries showing lesions caused by Coffee Berry Disease. There are also some sound and some completely dried-out diseased berries present.

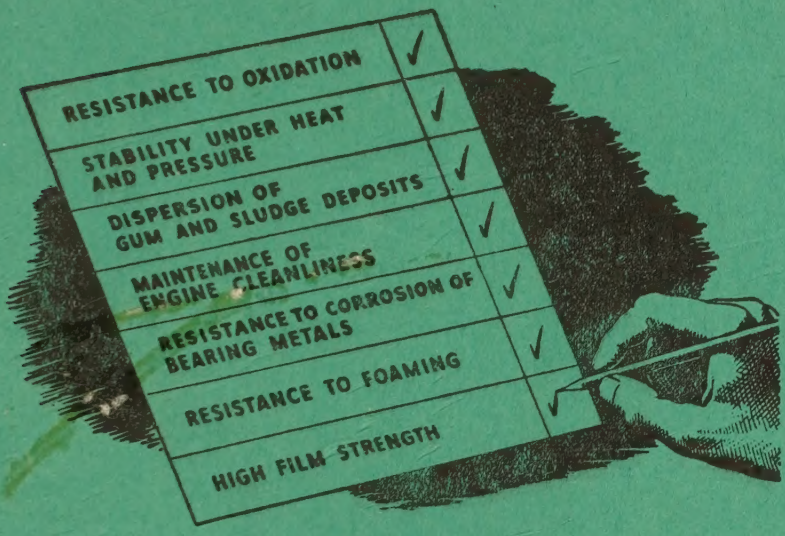
FIG. 3.—Spores of the Coffee Berry Disease form of *Colletotrichum coffeanum* Noack. Note the granular contents, the variability in size and shape and the tendency for them to be broader at one end than at the other.

FIG. 4.—An unbranched conidiophore bearing a spore. From a culture of the Coffee Berry Disease form of *C. coffeanum* Noack.

FIG. 5.—A branched conidiophore bearing young spores. From a culture of the Coffee Berry Disease form of *C. coffeanum* Noack.

FIG. 6.—A chain of chlamydospores, thick-walled units formed by the swelling of the cells of the mycelium. Note the irregularly lobed forms often assumed. Three conidiophores are also present towards the top of the picture.

Check the demands on your
DIESEL ENGINE LUBRICANT


RESISTANCE TO OXIDATION
STABILITY UNDER HEAT AND PRESSURE
DISPERSION OF GUM AND SLUDGE DEPOSITS
MAINTENANCE OF ENGINE CLEANLINESS
RESISTANCE TO CORROSION OF BEARING METALS
RESISTANCE TO FOAMING
HIGH FILM STRENGTH

All these properties are possessed by R.P.M. Delo, the first and foremost Diesel engine oil. R.P.M. DELO reduces wear, prolongs periods between overhaul and ensures full power from every gallon of fuel. It enables Diesel engines to be operated with heavier loads and greater economy. It is fully approved by leading engine manufacturers and operators throughout the world.

Call for a Caltex engineer to co-operate with you in cutting your engine maintenance and running costs.

R.P.M. DELO DIESEL ENGINE LUBRICATING OIL

is part of Caltex Reliable Service to Engineers

CALTEX *(Africa)* **LIMITED**

BRANCHES AND AGENCIES THROUGHOUT EAST AFRICA

FOR THE FARMER OF TO-DAY...

Maximum Traction • Tough Tread
Specially curved bars for self clearing
Long Life • Smooth riding

DUNLOP

TRACTOR TYRES

TRADE MARK

Built for the job!

A NEW TYRE DESERVES A NEW TUBE

DUNLOP RUBBER CO. LTD., BIRMINGHAM, ENGLAND

49X/73